AD-A195 976 INTEGRATING MULTISPECTRAL IMAGERY AND GROUND LEVEL HYPERSPECTRAL SIGNATURE DATA(U) ARMY ENGINEER TOPOGRAPHIC LABS FORT BELVOIR VA M B SATTERWHITE 1/1

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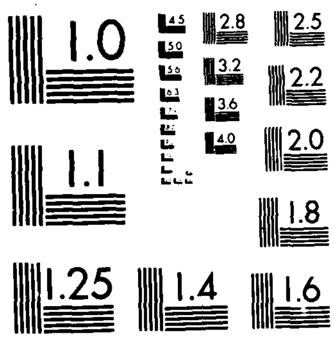

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Present day state-of-the-art digital image processing hardware and software can provide the image analyst the opportunity to use multispectral imagery (MSI) and, in the future, hyperspectral imagery (HSI) for evaluating and monitoring terrain and target features. However, the lack of training in the spectral signautes of terrain features can inhibit the analyst's interpretation of the multispectral false color composite image, prevent him from selecting the proper bands to achieve highest discrimination between the background and the target, and be a hinderance when he orders or displays a false color composite image.

Training our analysts in the spectral signatures of terrain features should result in better exploitation of the "pretty pictures". This training is equally as important as learning the operation of the digital image processing equipment. Without it the analyst uses the MSI/HSI image as a mpa or as a "photograph." He seldom or rarely uses the multispectral information within the image as part of his image analysis.

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The purpose of this paper is to discuss ground level spectral signature data and how they can be applied to the terrain analysis and targeting processes that use multispectral and hyperspectral imagery.

Integrating Multispectral Imagery and Ground Level Hyperspectral Signature Data

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Abstract

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Introduction:

Present day state-of-the-art digital image processing hardware and software can provide the image analyst the opportunity to use multispectral imagery (MSI) and, in the future, hyperspectral imagery (HSI) for evaluating and monitoring terrain and target features. Digital image processing hardware and software do an excellent job of displaying the digital image and making hard copy image products. Your system may prevent you from sharing this optimism, but the state-of-the-art systems being demonstrated by various vendors show that high quality and visually appealing imagery are possible today in hard copy and soft copy and they are not futuristics.

For the same geographical area, a large number of different false color composite images can be compiled by using different

3-band combinations provided by these sensor systems. Today's Landsat Thematic Mapper (TM) system has six bands in the visible-near infrared-middle infrared region (450 to 2350 nm) and a single thermal band (10.4 to 12.5 micrometers). Using the 6 visible to middle infrared band images, 20 different false color composite images (FCCI) can be made from the different 3-band combinations. Further, there are six different ways in which three bands can be displayed in blue, green, and red color space on the cathode ray tube (CRT) or in the yellow, magenta, cyan emulsions of color film (Figure 1). Also, there are a number of reasonable digital image transformations, e.g. band/band ratios, normalized difference vegetation index (NDVI), that manipulate the remotely sensed digital data and create algorithm images, which further increases the number of possible false color composite images.

Future MSI/HSI systems will give you data indigestion. These sensors, whether satellite or airborne, will not be limited to seven bands as is the Landsat TM satellite. They will have the capability to provide tens of bandpass images. Such systems are now operating in the R&D community and are exemplified by the Airborne Visible Infrared Imaging Spectrometer (AVIRIS), which can provide 220 bands of imagery (Figure 2). The permeation of 220 bands, selected 3 bands at a time, is 1.750 million different 3-band false color composite images. Each 3-band combination can be presented 6 different ways in color space, to give about 10.5 million different false color composite images, either on the CRT

or in color film.

Other false color composite images can be made using the 6 band thermal data available with the Thermal Infrared Multispectral Scanner (TIMS) or from radar imagery. These additional sources of remotely sensed data, when coupled with the Landsat imagery, increase the number of possible 3-band false color composite images.

The spectral resolution of our multispectral sensor systems has increased from 100 nm and 300 nm wide bands to 10 nm bands in just 10 years (Table 1). The spatial resolution has increased from 80 m pixels in Landsat MSS sensor data to 10 m pixels in the Spot panchromatic band. Future MSI/HSI systems will probably have spatial resolution around 5 m or better. How many spectral bands

Table 1

Characteristics of Different Multispectral Sensor Systems

Sensor System	band width (nm)	number of bands	spatial resolution (m)	pixels* covering a 185x185 KM area (in millions)
Landsat MSS	100/300	4	80	5.35
Landsat TM	60/140	7	30	38.03
Spot	80/420	4	10	342.25
AVIRIS	10	220	10	342.25
"X"	10(?)	?	5	1369.00

* Land surface area covered by a Landsat MSS or TM scene.

and which bands will be needed are presently a major concern in the research and development community. We can be certain that future satellite systems will have high~~t~~ spatial and spectral resolution and that selecting the proper band images will not be an easy task.

If we are going to fully understand what these "pretty pictures" represent in terms of the terrain features, the vegetation-soil mosaic, and the targets, we must go beyond our present level of image exploitation. The approach I propose is a "ground-up" approach, which seeks to understand the spectral signatures of various terrain features, and apply this knowledge to the gray scale of a band image, or the color scale of the FCCI.

Troops of the 29th Engineers Battalion (Topographic) and 64th Engineer Detachment (Terrain) were quite proficient in using an off the shelf commerical digital image processing system; the Remote Image Processing System (RIPS). Although I view RIPS as an entry level system, it has viable basic training applications. These Army topographic/terrain units could readily manipulate the digital image data and performed basic image processing, e.g., density slicing, color enhancement, false color composite image generation, and algorithm image generation and display. Today, Department of Army units are purchasing more powerful multispectral imaging systems such as 'ERDAS' or 'ELAS' which do the same basic image processing, although these are more sophisticated and much faster image processing systems. After the

excitement and newness of the system have abated, I still receive the same type of questions and inquires as I did with the RIPS:

- Where do I go from here?
- Which band images should I select for creating the FCCI?
- How do I interpret the FCCI?
- How do I incorporate these data into my normal operation?

Some of these questions can be resolved through training in the multispectral characteristics of terrain features. Others can be resolved by incorporating MSI into their geographical information system (GIS) data bases and using MSI to update the GIS, and for monitoring and surveillance.

Over the past five years, I have provided training to Army terrain analysts at the

Defense Mapping School, Fort Belvoir, VA
29th Engineers (Topo), Fort Shafter, HI
64 Engineers (Terrain), Fort Hood, TX
USAICS, Fort Huachucha, AZ

The analysts have varied in their education level from high school to university masters degrees. Most were enlisted personnel, grades E3 to E9, but clustered in grades E5 to E7. There have been a few Warrant Officers and Commissioned Officers, CW-2 to CW-4, and 2d Lieutenant to Major. I have seldom found a lack of interest or capability. The troops are very capable in understanding multispectral signatures of the vegetation-soil

mosaic and applying these data to their interpretation of MSI. The analysts have few problems in using the computer hardware and software after some training and on-the-job experience. In my opinion, the single biggest stumbling block to the Army's terrain analyst's exploitation of MSI/HSI is a lack of training in the spectral characteristics of the terrain features and the targets of interest.

The lack of training inhibits the analyst's interpretation of the multispectral false color composite image. It prevents him from selecting the proper bands to achieve highest discrimination between the background and the target. It hinders him when he orders a false color composite image or displays a false color composite image on the CRT. As a result, the analyst uses the image as a map or as a "photograph." He <u>seldom or rarely</u> uses the multispectral information within the image as part of his image analysis and exploitation process. He <u>usually</u> evaluates the image in terms of image areas having recognizeable color similarities and differences. His knowledge for evaluating the color differences is <u>limited</u> to the common generalities, such as green vegetation is "red" on the false color composite image. This is a correct inference made from our previous experience with color infrared (CIR) photography, but the analyst has assumed the image being viewed is a standard Landsat product composed of MSS bands 2, 3, and 4 or TM bands 2, 3, and 4 which have been assigned to the blue, green and red "color guns" of the CRT, or to the yellow, magenta, and cyan film emulsions, respectively.

Green vegetation is depicted by a red color in CIR photography and in the standard Landsat MSS and Thematic Mapper products, but the analysts commonly do not understand why this is so, nor the process that brings about this presentation. The large number of combinations of Landsat TM bands and the flexibility to associate any band with any film color emulsion or CRT "color gun" means that a red image color may not represent vegetation in many Landsat Thematic Mapper false color composite images. The analyst can vary the selection of TM bands forming the composite image and, in this manner, green vegetation can be presented as either the blue color, the green color, or the red color in the false color composite image.

To effectively use spectral signature data in your MSI/HSI analysis you should have at your disposal the spectral characteristics of the background materials and the target of interest. If the target and background do not have sufficient reflectance contrast in at least one bandpass you have selected for the FCCI, you <u>will</u> <u>not</u> be successful in finding and discriminating the target. You can understand and use spectral signatures of the vegetation-soil background, and yet you don't need the spectral signatures of all the plant species in the world, nor the spectral signatures of all the soil and rock materials. From my experience over a 10 year period of making laboratory and field spectral measurments and from the data presented in the scientific literature, there are sufficient commonalities among groups of vegetation and classes of soil and

rock that we need only to have in mind a small number of spectral signatures for most purposes. For example, in the 400 to 1100 nm, region vegetation can probably be described by 7 to 10 general spectral reflectance curves (Figures 3 and 4) and soils and rocks by another 7 to 10 spectra (Figure 5 and 6).

Some differences will exist between vegetation spectra of the same plant species, but these differences usually occur in the NIR region and are related primarily to the plant growth parameters. Depending on your mission, e.g. monitoring agricultural crops or assessing crop production, these NIR reflectance differences may be important. In the MIR region, vegetation is less variable and appears more related to percent cover in the sensor field of view (FOV) and is less variable in terms of the plant growth parameters or plant water. For the geologist and the soil scientist, the soil spectra in the 1300 to 2500 nm region are important because of the characteristic absorption bands, from which different soil and rock components are identified.

There are a number of on-going efforts that are compiling spectral signature catalogs of terrain and target features. Our efforts at USAETL center on vegetation, soil, and rock features and factors of these surfaces that cause the spectra to vary from one sample to the next. We are compiling these data into spectral signature data sheets for various materials (Figure 7).

A problem that I give my multispectral classes may help

illustrate how these spectral signature data can be used with Landsat MSS/TM imagery. I recogniaze the spatial resolution limitations of the Landsat image in this problem, but conceptually, the problem illustrates the use of ground level spectra for proper sensor band selection and the probable detection of targets or features. If you are standing in a forest tree line, in your woodland fatigue jacket;

- Do you blend with the background?
- If you are searching the tree line, can you find a person who is wearing the fatigue jacket?

Assume that your sensor system allows you to select any Landsat Thematic Mapper spectral band in the visible-mir spectrum.

The jacket is a mosaic of four colors, so we measured the spectral reflectances of each color and by sampling we determine the percent of each color in the cloth (Figure 8). Based on these data we calculated the mean reflectance curve of the jacket. This same procedure can be use for the desert fatigue jacket (Figure 9).

An effective camouflage is one whose dyes emulate the background materials. If there is little reflectance contrast you can expect to hide, but if there is high reflectance contrast you can expect to be found. Based on these spectral signatures and those of green leaves (Figure 3), the following questions are

addressed concerning the woodland field jacket;

Is your fatigue jacket an effective camouflage;

- in the visible region (400 to 700 nm)?
- in the CIR photographic region (500 to 900 nm)?
- in the middle infrared region (1300 to 2500 nm)?

- In which Landsat TM bands are you most likely <u>not to be found</u>?.
- In which Landsat TM bands are you most likely <u>to be found</u>?
- In what spectral regions would you be successful in finding the person if future MSI systems have 10 nm resolution?

Based on the limited number of camouflage paints and materials that we have measured some materials make good camouflage in the visible to near infrared region (400 to 1000 nm). The tan, brown, and black colored fabrics emulate the soil and rock background in the 1300 to 2500 nm region (Figure 10), but the tan, brown, and black paints and most green colored fabrics and paints do not emulate the intended background materials (Figures 10 and 11). The result of our "high tech" revolution over the last 10 years now provides sensor systems that are sensitive in spectral regions for which these paints and camouflage materials were never intended to be effective. This does not mean that new materials and paints cannot be developed.

With the expectation of a large number of spectral band images and multitemperal acquisition, various data compression techniques

will be necessary for these image data sets. Instead of evaluating tens of band images, these can be reduced into a single algorithm image, or to a single false color composite image, by very judicious band image selection so that the needed spectral information is compiled in a single algorithm image. There are several algorithms being used in the civilian sector that can compile imagery data; e.g. the brightness - greenness transfromation, the normalized difference vegetation index (NDVI) or simple band:band ratios. The brightness and greenness transformations may be perferred since they can reduce 4, 5, or 6 band Thematic Mapper image data into 2 band algorithm image data. The brightness transform summarizes the intra-band reflectance contrast between different surfaces. The greenness transform summarizes the inter-band reflectance contrast between bands for the same surface. As an example, the mean reflectance values for each spectra in Figures 3 to 11 were calculated for the five spectral region corresponding to Landsat Thematic Mapper bands 1, 2, 3, 4, and 5. These five values were reduced to a brightness algorithm value and a greenness algorithm value for each spectra. Figure 12 shows the relations between brightness and greenness transformation values of these surfaces. This same technique has been used with Landsat digital imagery. The Landsat image pixel values transformed into algorithm values, that are used to create a "brightness algorithm image" and a "greenness algorithm image".

Applications of these or other transformations to Landsat Thematic Mapper imagery would enhance our monitoring and

surveillance and rapid identification of multitemporal changes. If change occurred between the day one and day two overpasses, these changes would be depicted in the false color composite algorithm image. This technique has been successfully used by some image analysts. I feel a greater potential use lies within terrain analysis, in which the multitemporal algorithm images are compiled into false color composite images, then the image color differences are evaluated in terms of expected vegetation phenology, plant growth parameters, soil conditions, and the associated spectral signatures. This may be too complex a problem for many analysts, but research may show that these transformations could be used within an artificial intelligence (AI) "smart" approach that uses decision logic trees based on plant ecology, geomorphology, geology, soil science, and recent climatic conditions.

The analysts of the future must use sophisticated approaches in their image analysis procedures. The process must use the wealth of GIS information and data available for the area of interest. Remotely sensed imagery, such as Landsat Thematic Mapper data must become an integral and working part of any geographical information system. AI procedures must be developed that automate some of the terrain evaluation processes, together with the multispectral imagery. The fuller exploitation of present and future MSI/HSI images will require some knowledge of the spectral signatures of terrain features and targets for proper band image selection and for achieving feature detection and

identification.

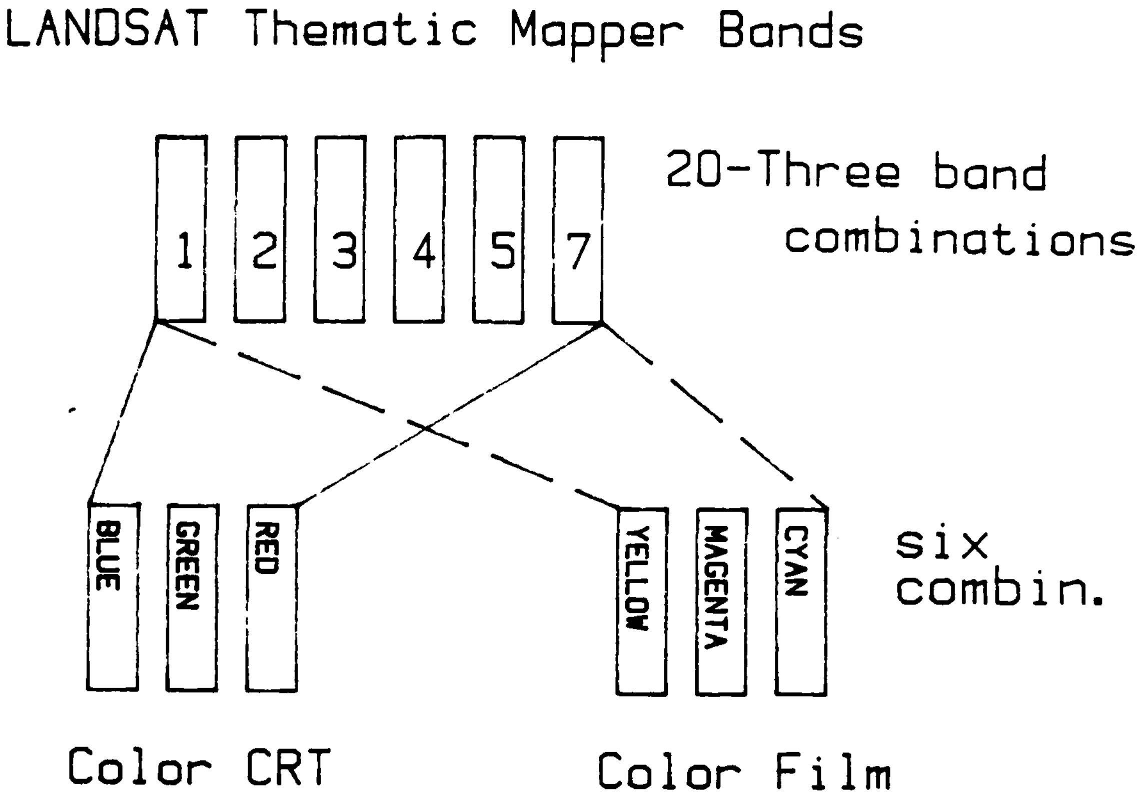
The future applications of HSI sensor data to terrain analysis appear very favorable, however, major obstacles must be resolved:

1) Decisions must be made that commit capital and human resources for implementing state-of-the-art MSI/HSI systems within our topographic and terrain analysis units.

2) A determined effort must be made to properly train our analysts to use state-of-the-art hardware and software so that they can exploit the MSI/HSI image. This would include training in multispectral signatures, color image generation and image interpretation procedures.

3) A decision to give time and resources for the analysts to practice and gain confidence in the exploitation of MSI so that they will know when a multispectral sensor system can provide primary or ancillary data.

4) Develop an environment that keeps your trained analysts working in the topographic and terrain analysis environment.



120 Possible Combinations of
6 TM Bands Presented in Color

Figure 1: Illustration of the Number of TM Band - Color Medium Combinations

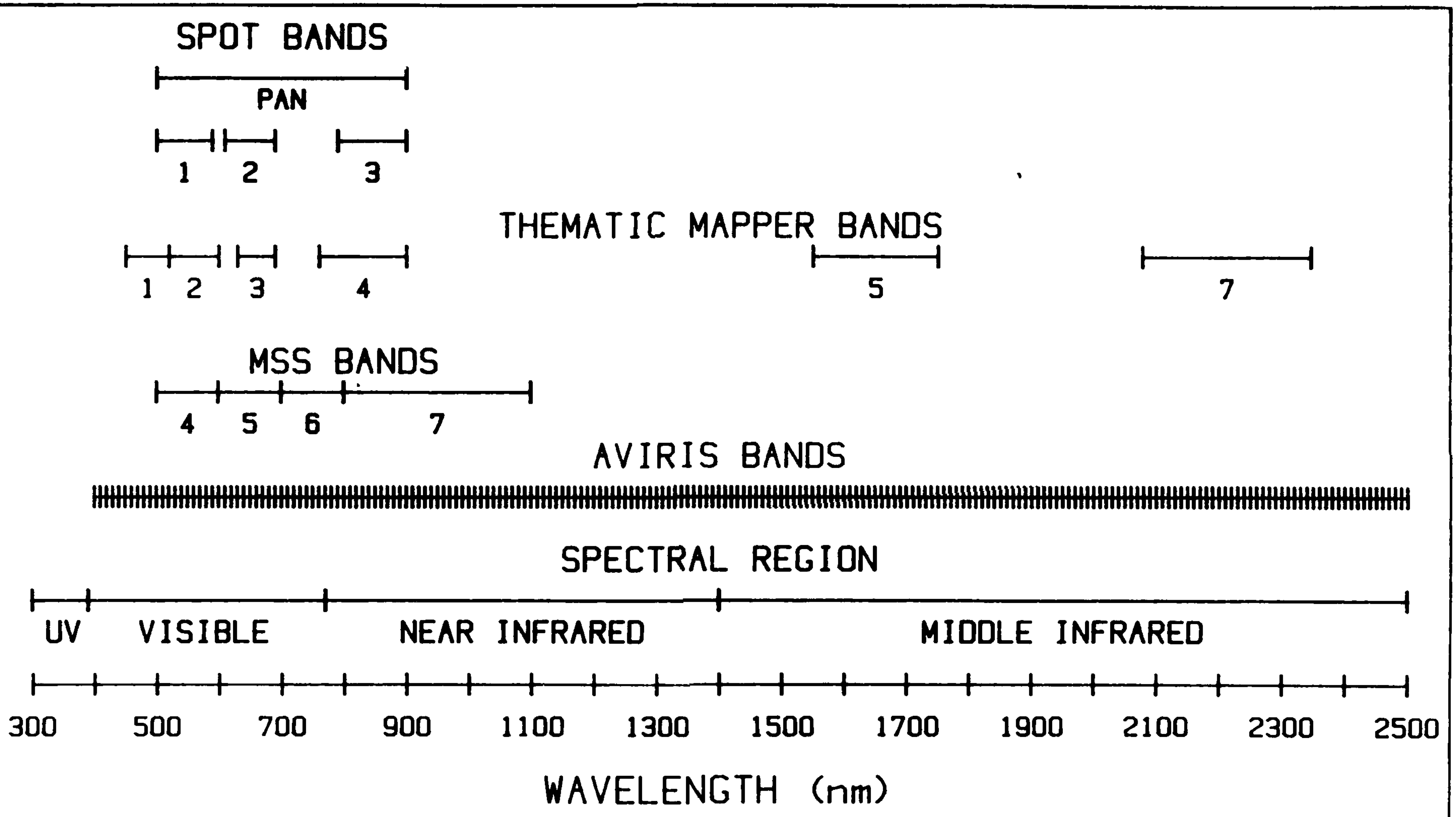


Figure 2. Spectral Bandpasses of Landsat MSS, Thematic Mapper, SPOT and AVIRIS

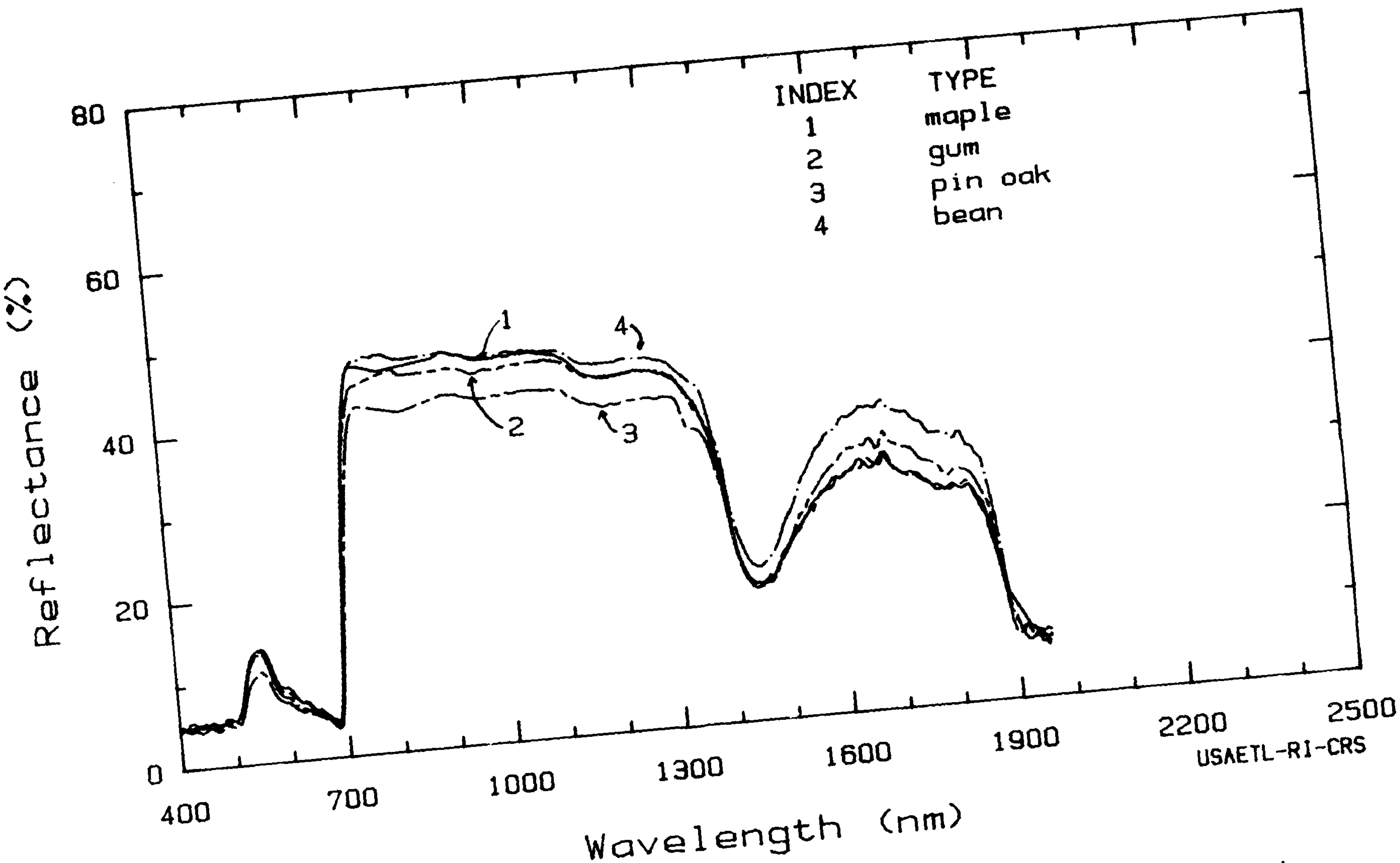


Figure 3. Reflectance Spectra of Green Plant Leaves. Ft. Belvoir, VA, October 1987.

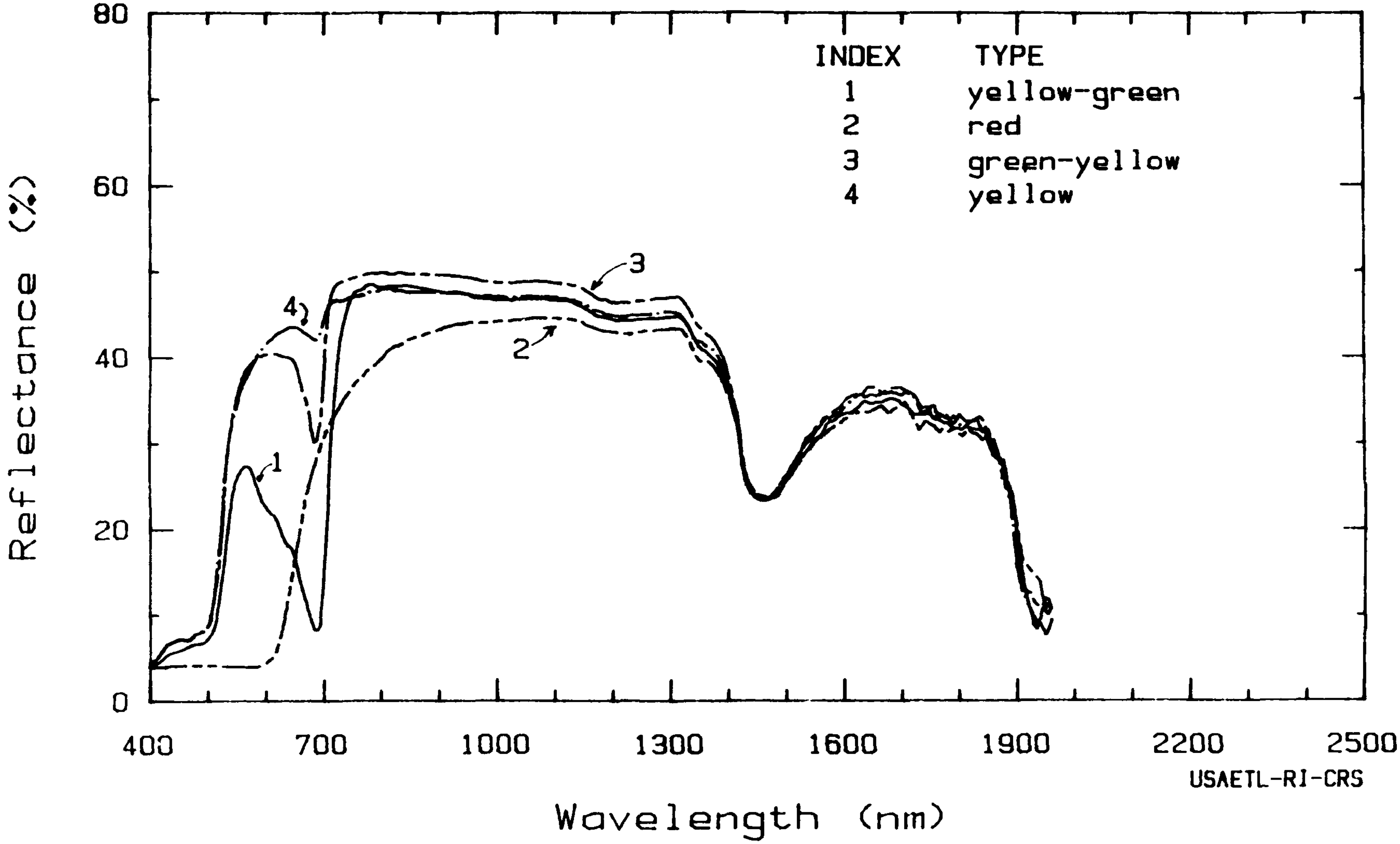


Figure 4. Reflectance Spectra Senescing Maple Leaves, Ft. Belvoir, VA, June 1987.

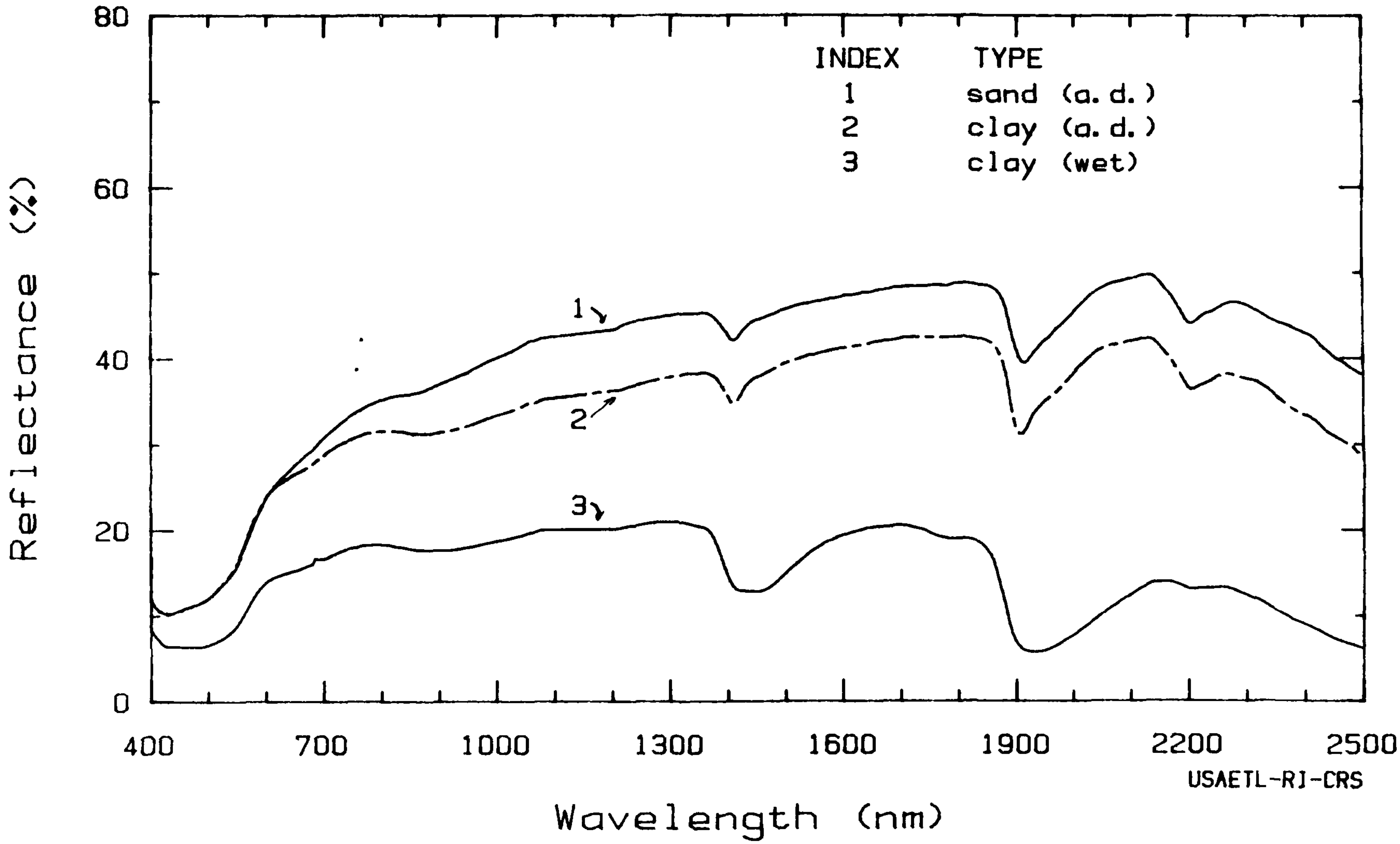


Figure 5a. Reflectance Spectra of Different Soils, Ft. Belvoir, VA, June 1987.

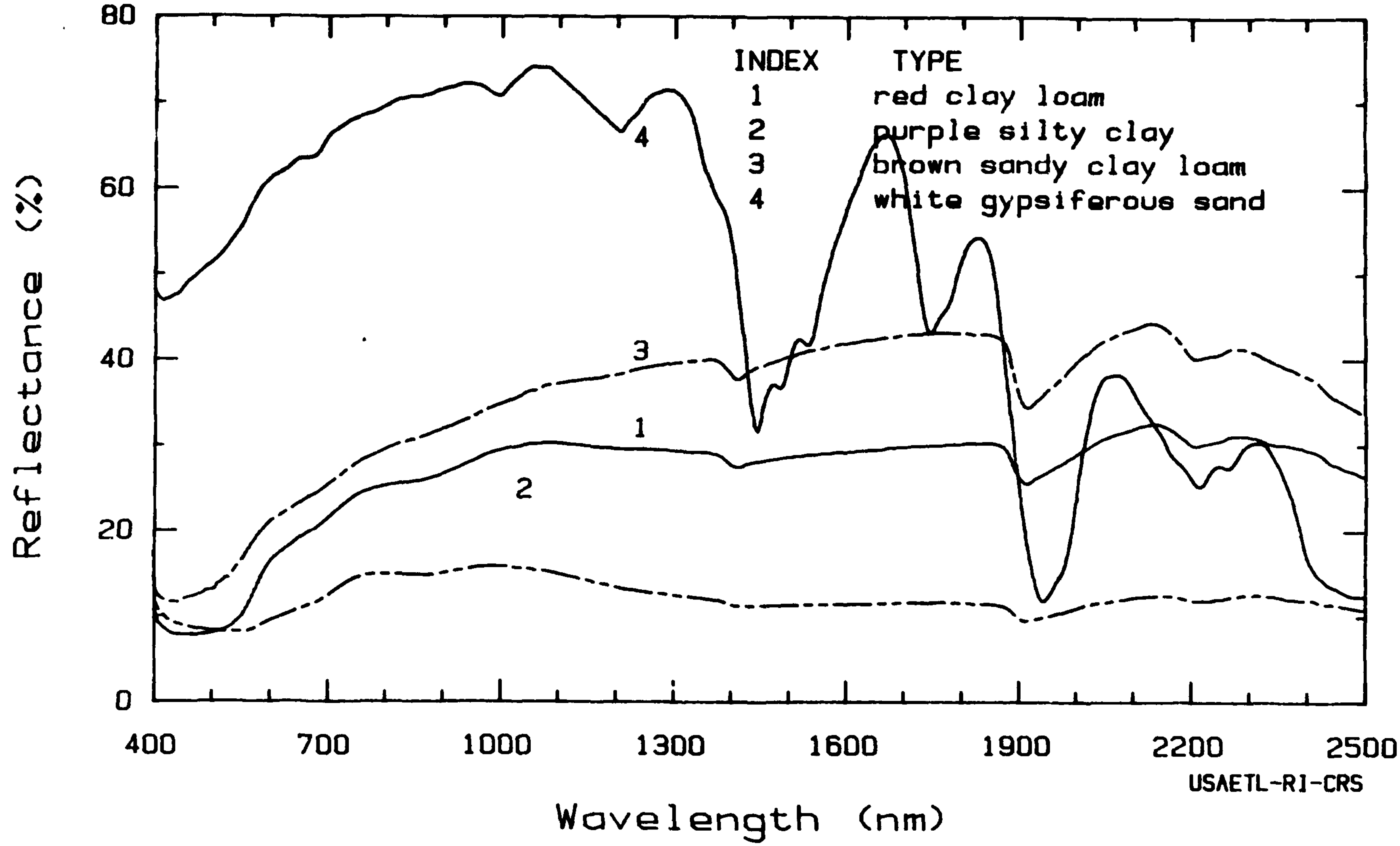


Figure 5b. Reflectance Spectra of Different Soils
Ft. Belvoir, VA, May 1988.

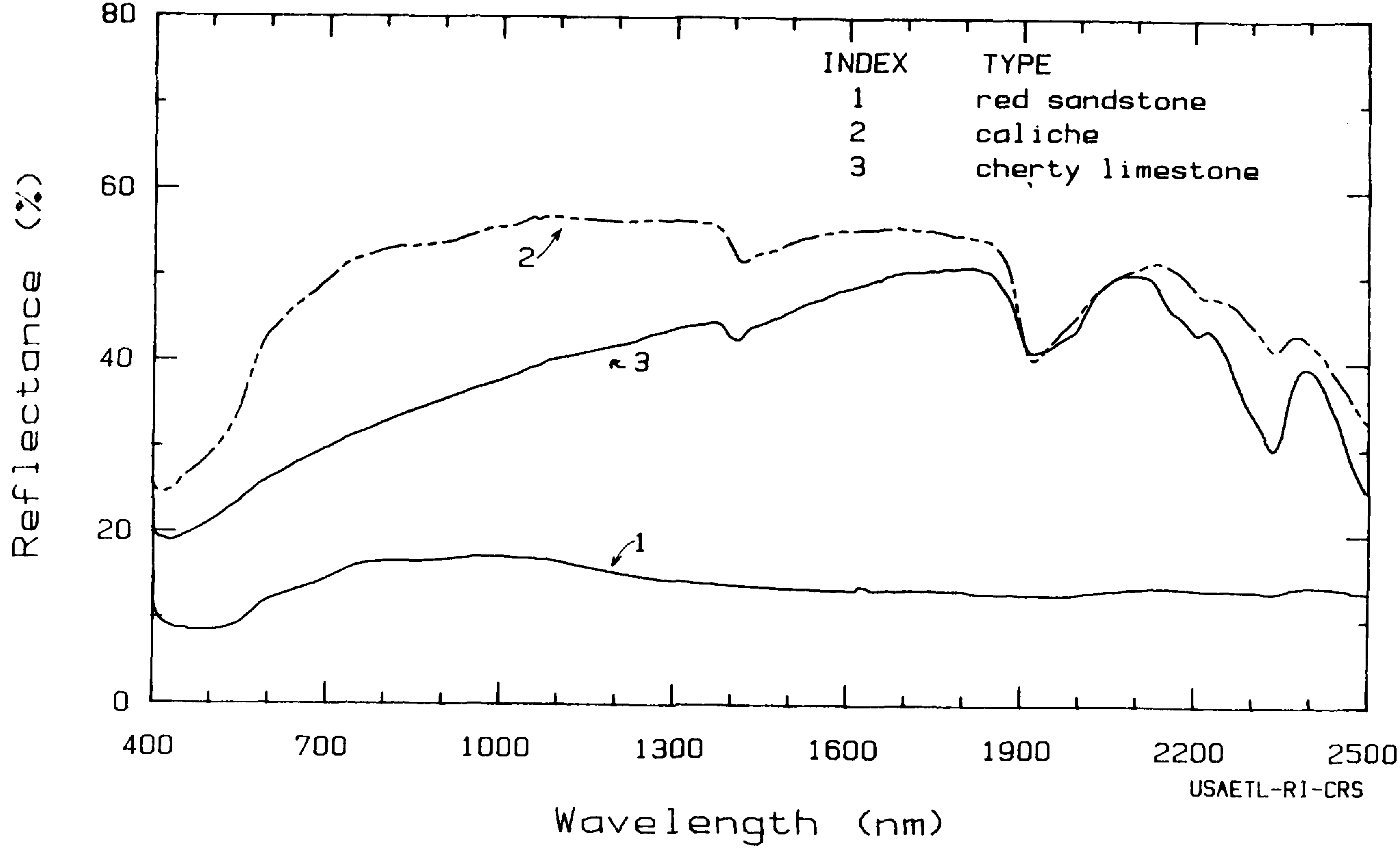


Figure 6a. Reflectance Spectra of Different Rocks,
Ft. Belvoir, VA, May 1988.

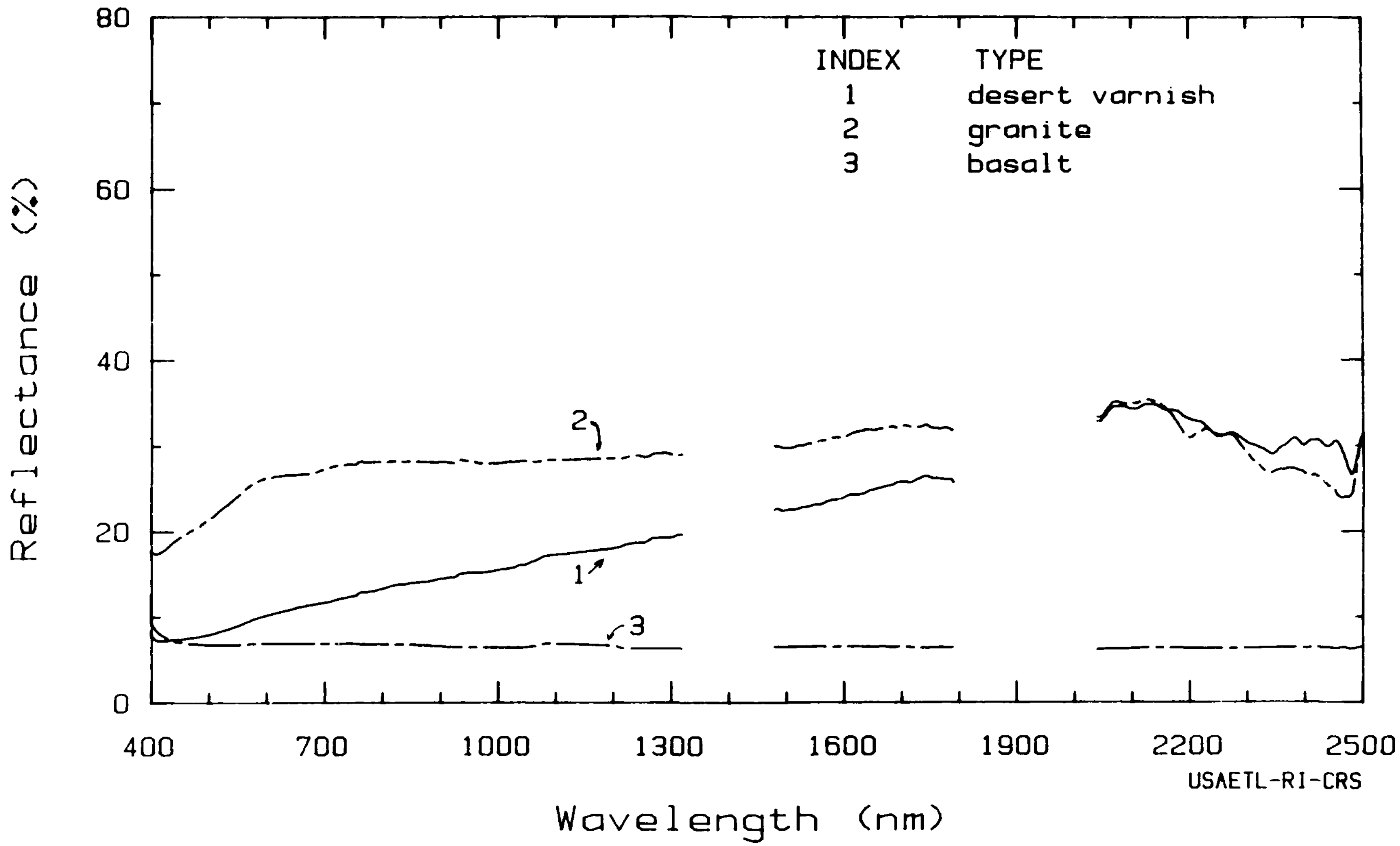


Figure 6b. Reflectance Spectra of Different Rocks,
Ft. Belvoir, VA, May 1988.

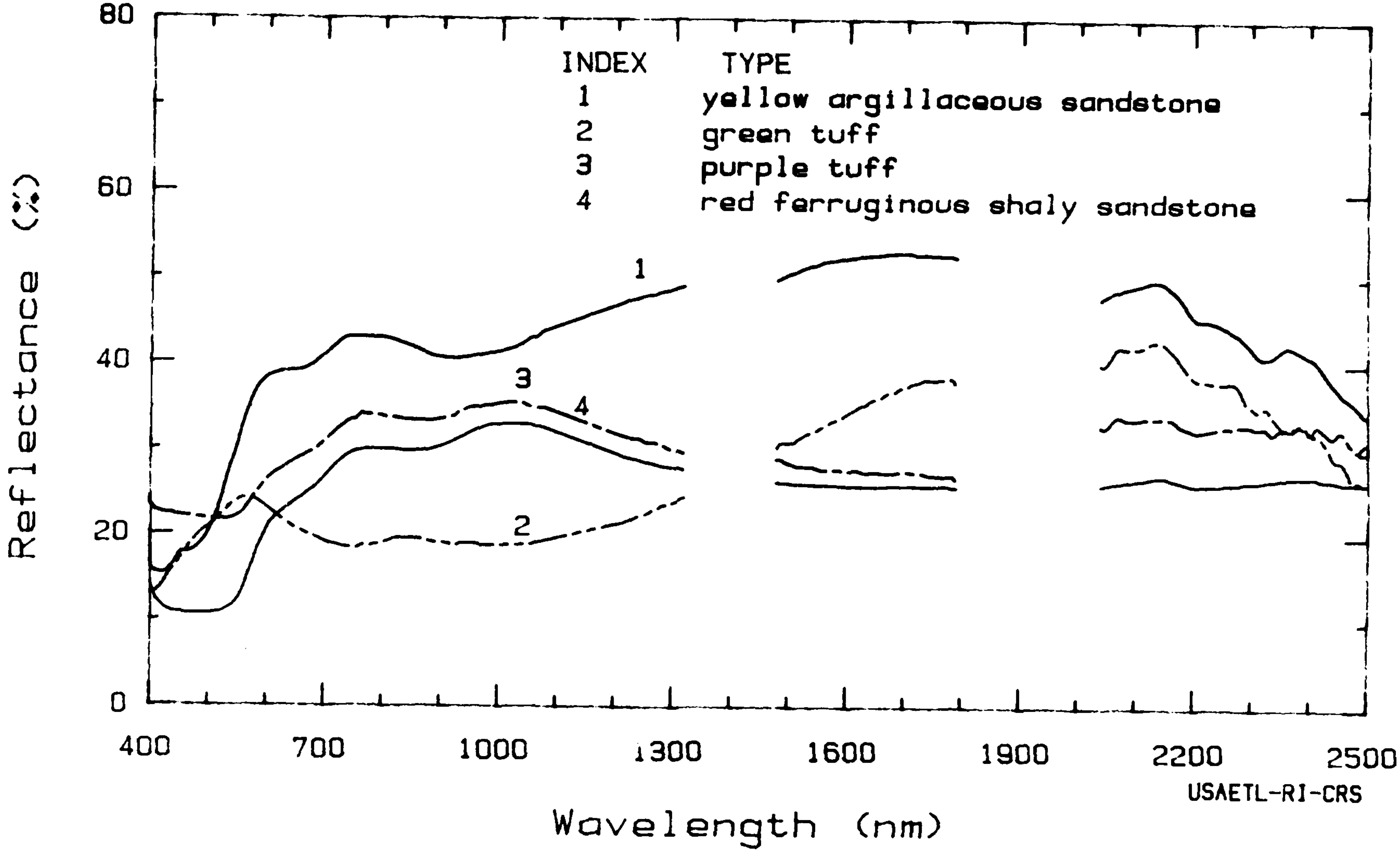


Figure 6c. Reflectance Spectra of Different Rock Surfaces, Ft. Belvoir, VA, May 1988.

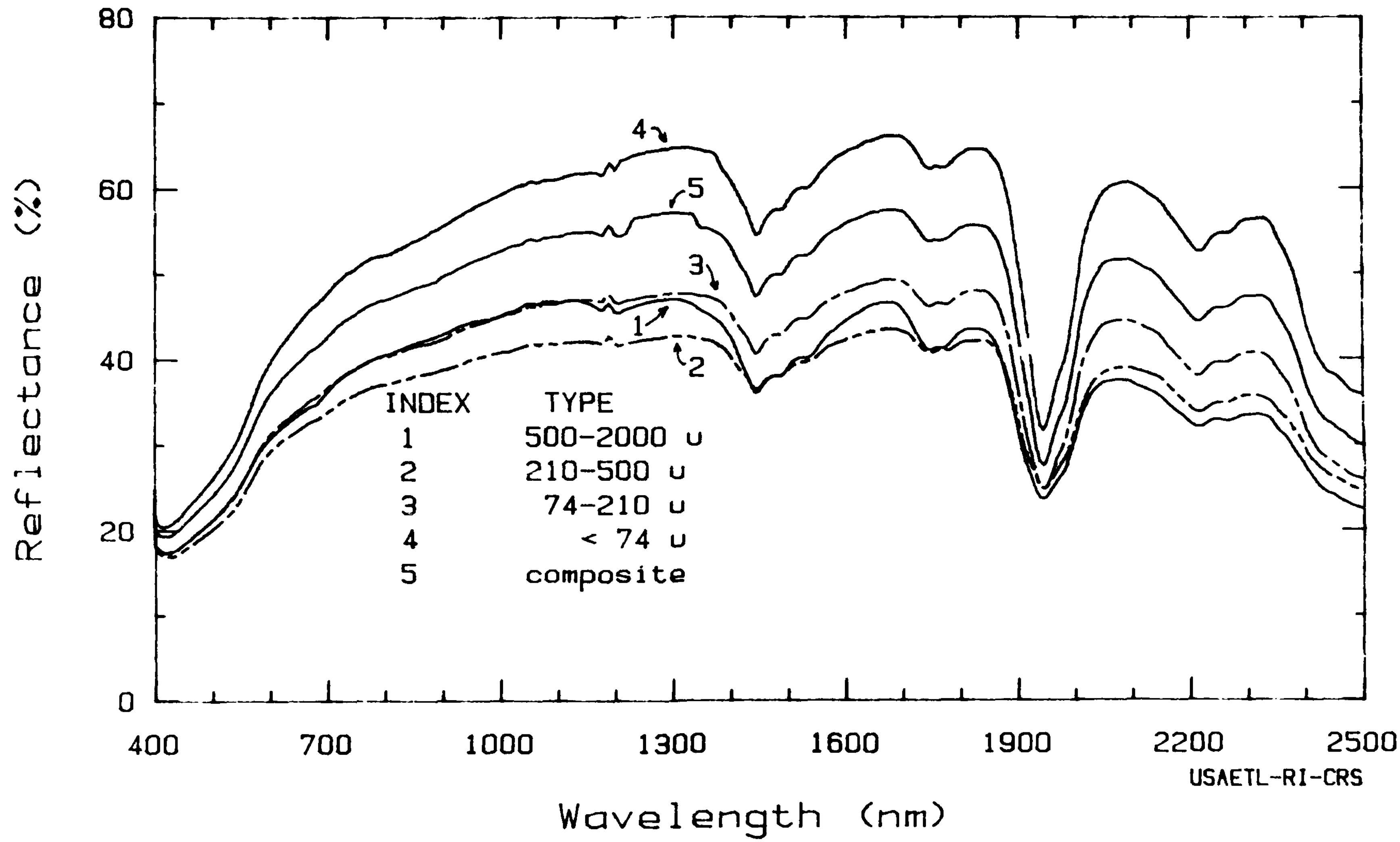


Figure 7. Reflectance Spectra Air Dry Silt Loam Sieve Separates. Ft. Belvoir VA. 2/87.

Laboratory Spectral Reflectance of Soil

Soil Texture: Silt Loam (air dry) Date Collected: 20 Feb 1986
Taxonomy: Aridisol Sample Number: AU-08
Mapping Unit: Dona Ana-Reagan Association 1/

Site Location: Dona Ana County, New Mexico, USA
32.7 deg. N. Latitude; 106.7 deg. W. Longitude

Procedures:

Spectroradiometric: Geophysical Environmental Research, Mark IV, spectroradiometer, SN:FBV-024; 4 degree field of view, spectral resolution 1.5 nm between 360 & 1300 nm, and 3.5 to 4.5 nm between 1300 & 2500 nm. Nadir viewing angle. Viewing height, 48.5 cm. Light source was a Lowel tota, 500 watt, Tungsten-Halogen lamp at a color temperature of 3200 degree K. Pressed Halon reference standard.

Sample: The air dried composite soil sample was passed through a soil sieve with openings of 2000 um and a subsample was taken (Index E). Remaining sample was passed through a nest of soil sieves with openings of 500 um, 210 um, 74 um, and pan. Each sieve separate was analyzed spectroradiometrically, (Indices A, B, C, and D, respectively). Moisture contents were determined gravimetrically at the time the spectra were taken.

Physical & Chemical Properties of Composite Sample: 2/

Composition: 40.0% Sand, 54.0% Silt, 6.1% Clay
Moisture Content: 4% to 11% (O.D. basis)

Mineralogy: Kaolinite, 7.9%; Fe-Oxyhy, 1.7%; Smectite, 7.7%; Mica, 11.4%; Calcite, 7.0%; Quartz, 32.3%; Gypsum, 29.5%

Ref: 1/ SCS-USDA, 1980, Soil Survey of Dona Ana Co., New Mexico.
2/ Ben Hajek, Unpublished soil data (sample AU8-E), Agron. Dept., Auburn Univ., AL.

Mean Reflectance(%) in Landsat 4 Thematic Mapper Bands.

Curve Index	Band 1	Band 2	Band 3	Band 4	Band 5	Band 7
	450-520 nm	520-600 nm	630-690 nm	760-900 nm	1550-1750 nm	2080-2350 nm
A	20.4	26.5	33.9	41.3	44.4	34.1
B	19.4	25.0	32.1	37.6	42.3	36.0
C	20.3	26.5	34.5	41.0	47.9	41.0
D	24.8	33.3	44.8	53.2	64.4	56.4
E	23.0	30.4	40.2	47.8	56.0	47.7

Compiled by: Melvin B. Satterwhite. Sheet No: 00008.
USAETL-RI-CRS.

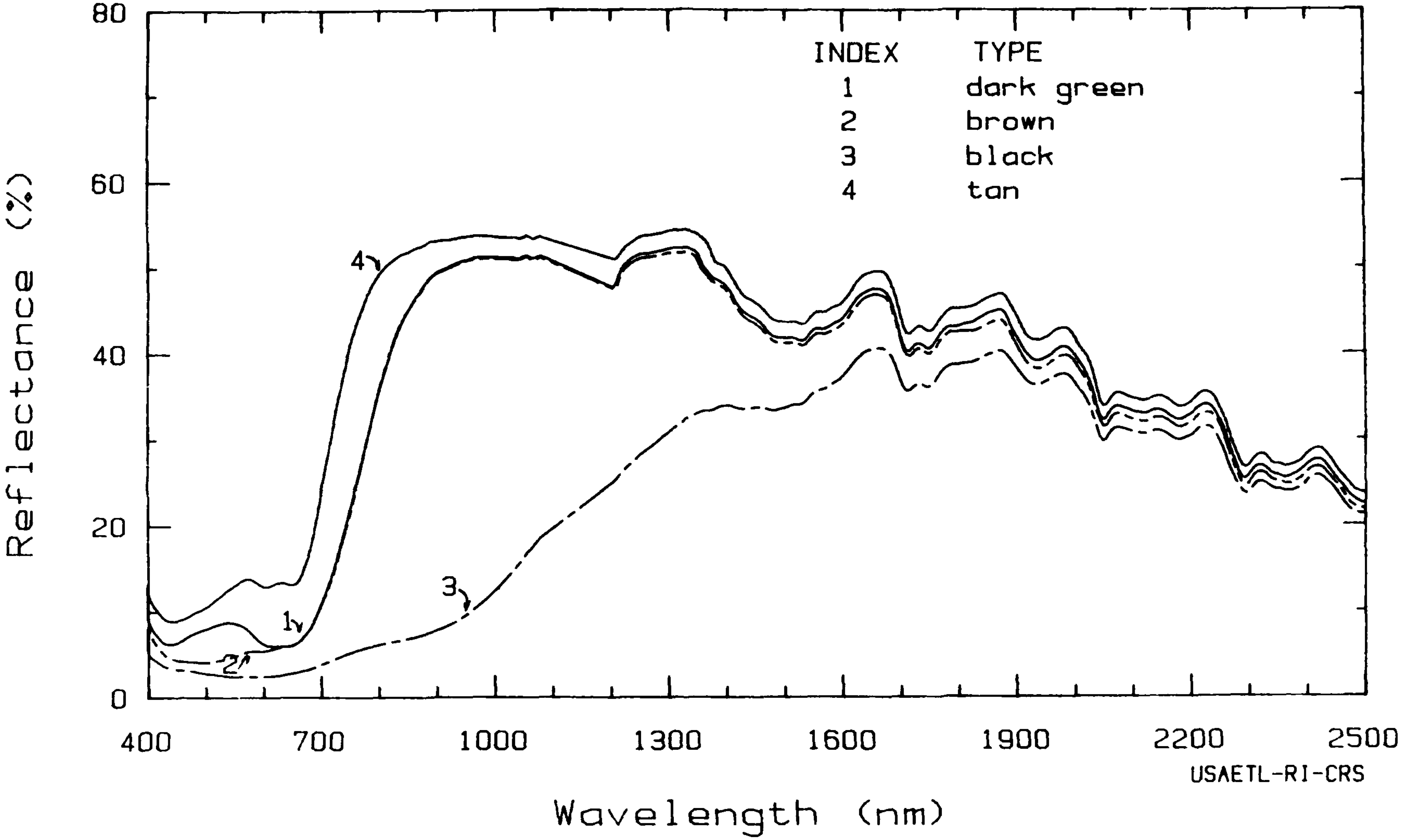


Figure 8. Reflectance Spectra of Woodland Fatigue Jacket, Ft. Belvoir, VA, October 1987.

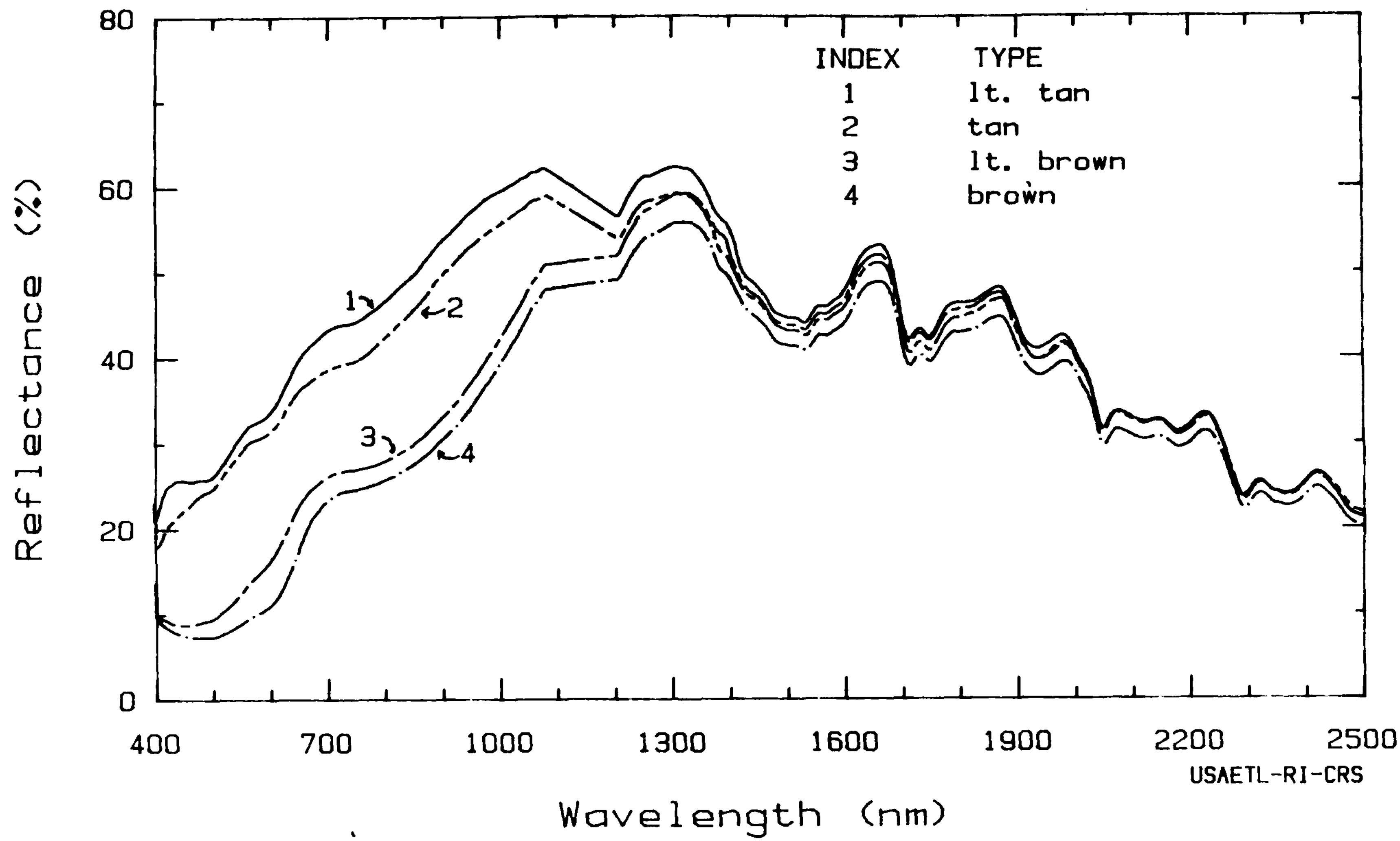


Figure 9. Reflectance Spectra of Desert Fatigue, Jacket, Ft. Belvoir, VA, September 1987.

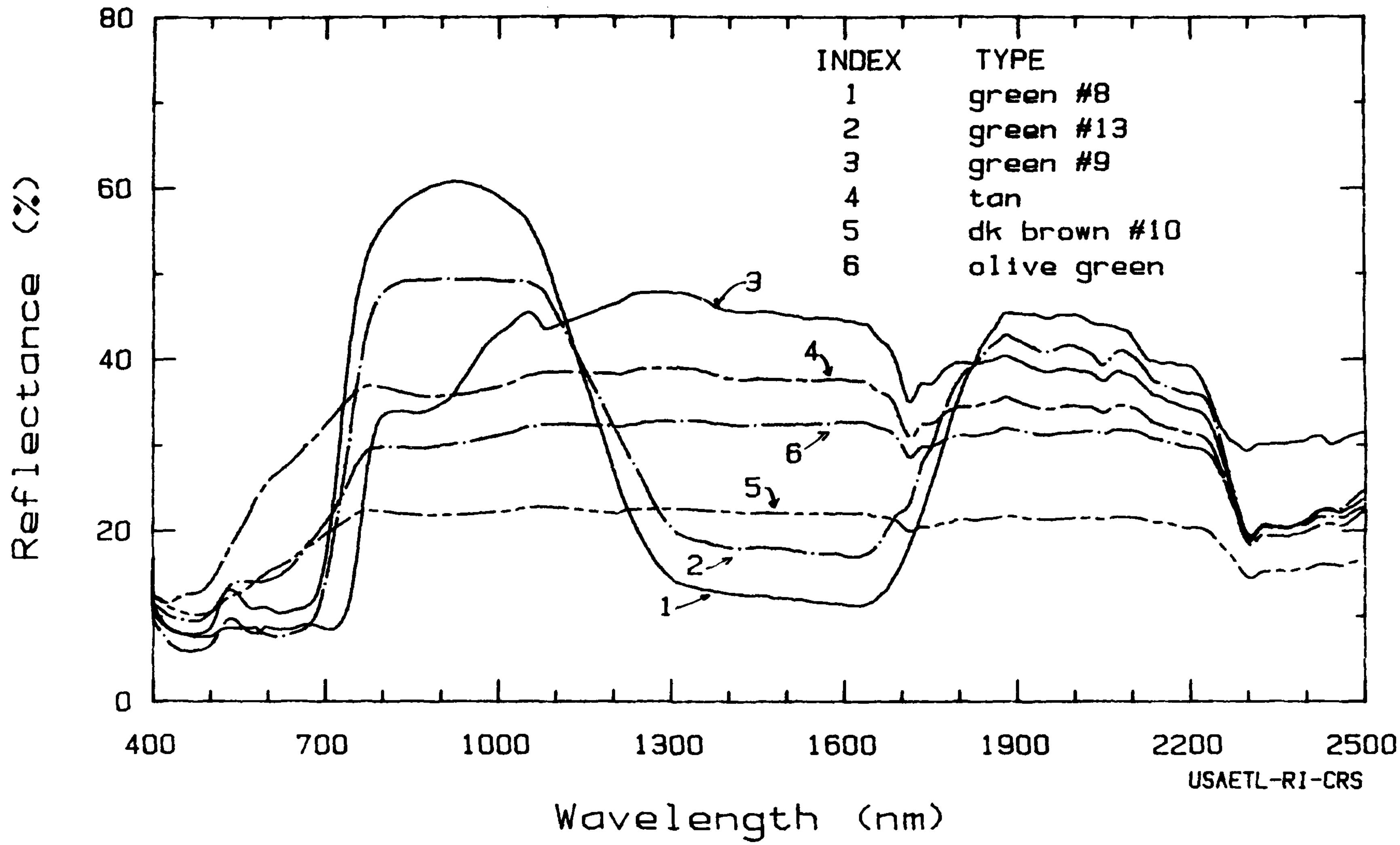


Figure 10. Reflectance Spectra of Camouflage Netting, Ft. Belvoir, VA, May 1988.

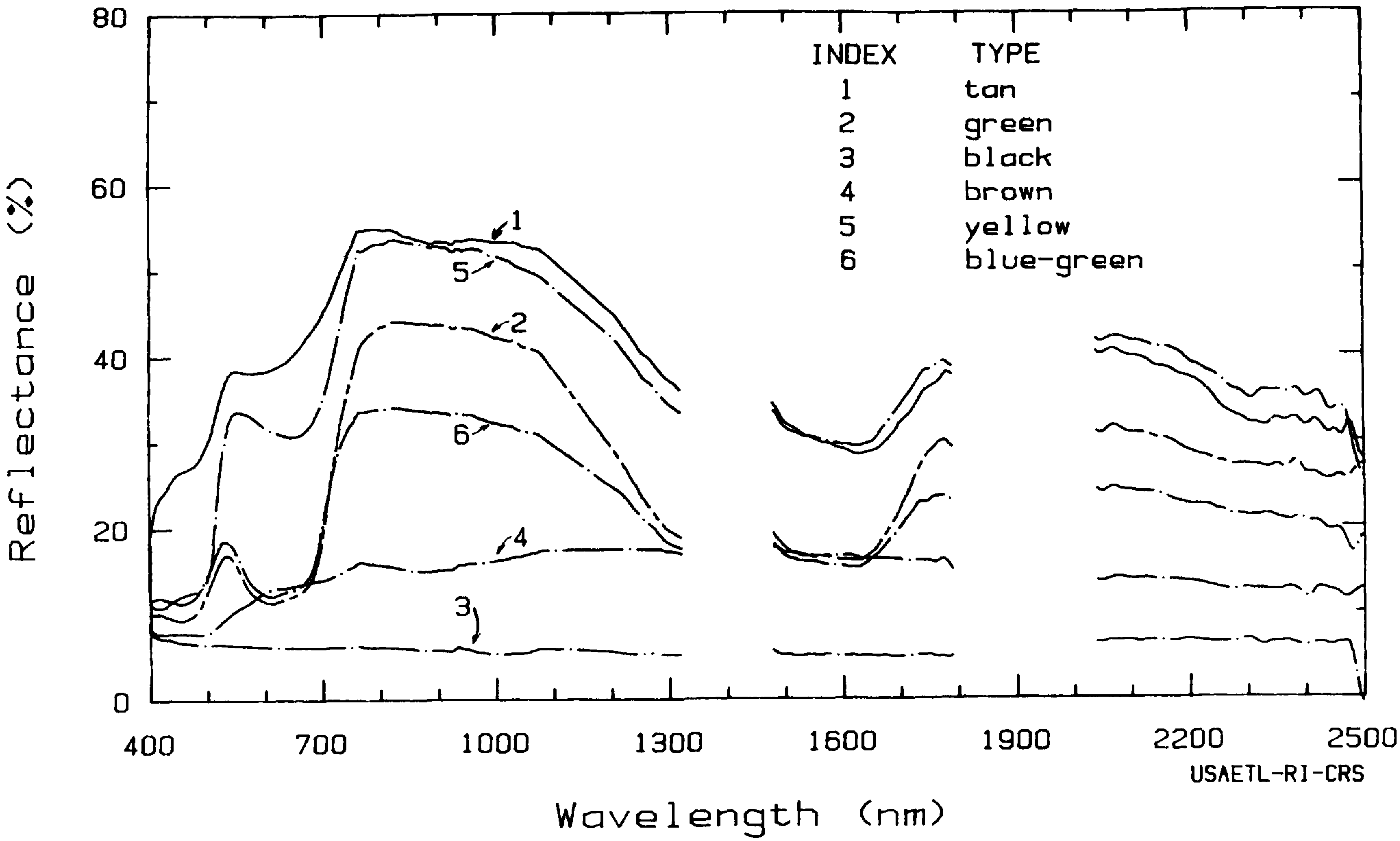


Figure 11. Reflectance Spectra of Vehicle Paint, Ft. Bliss, TX, September 1987.

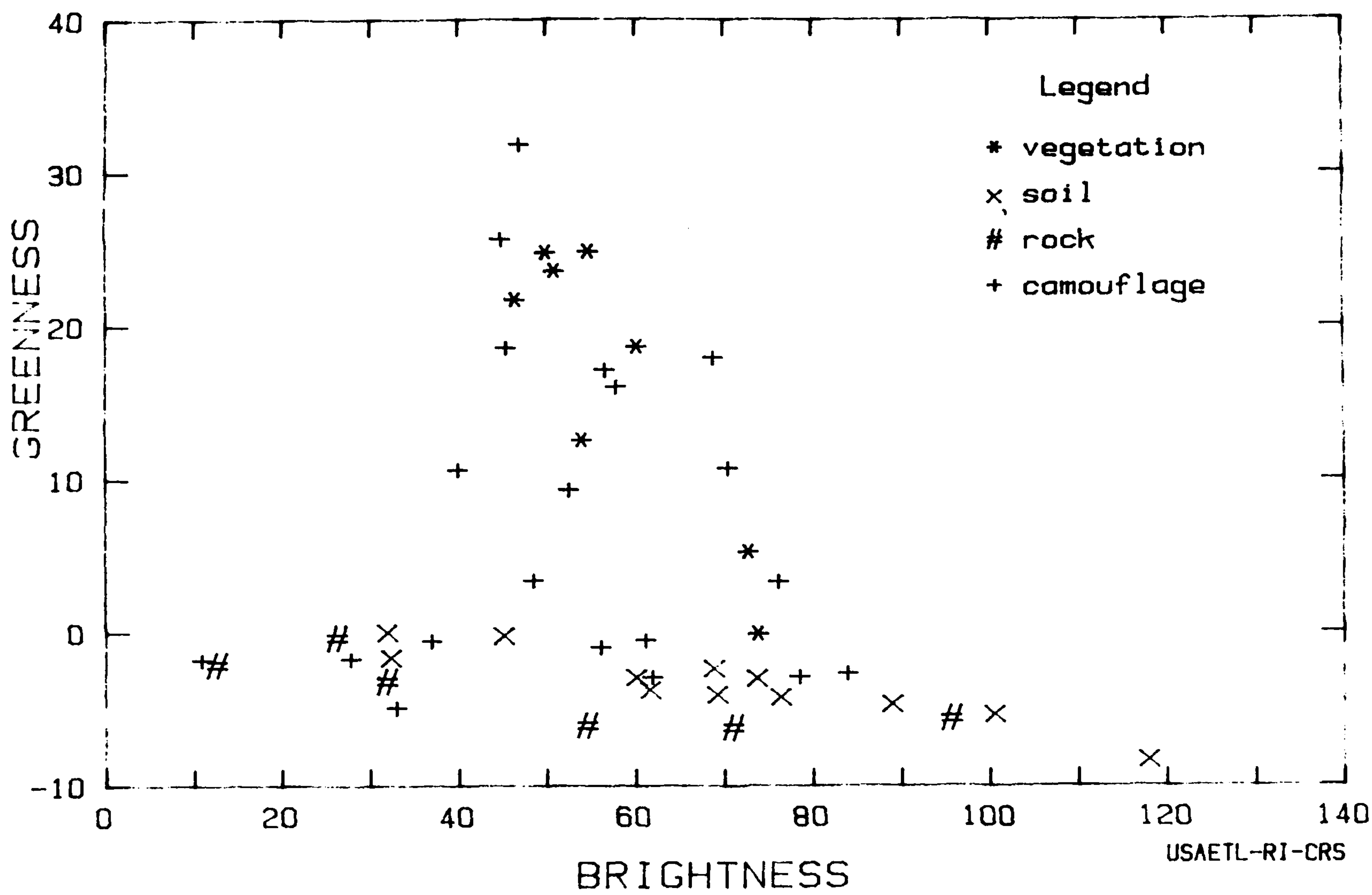
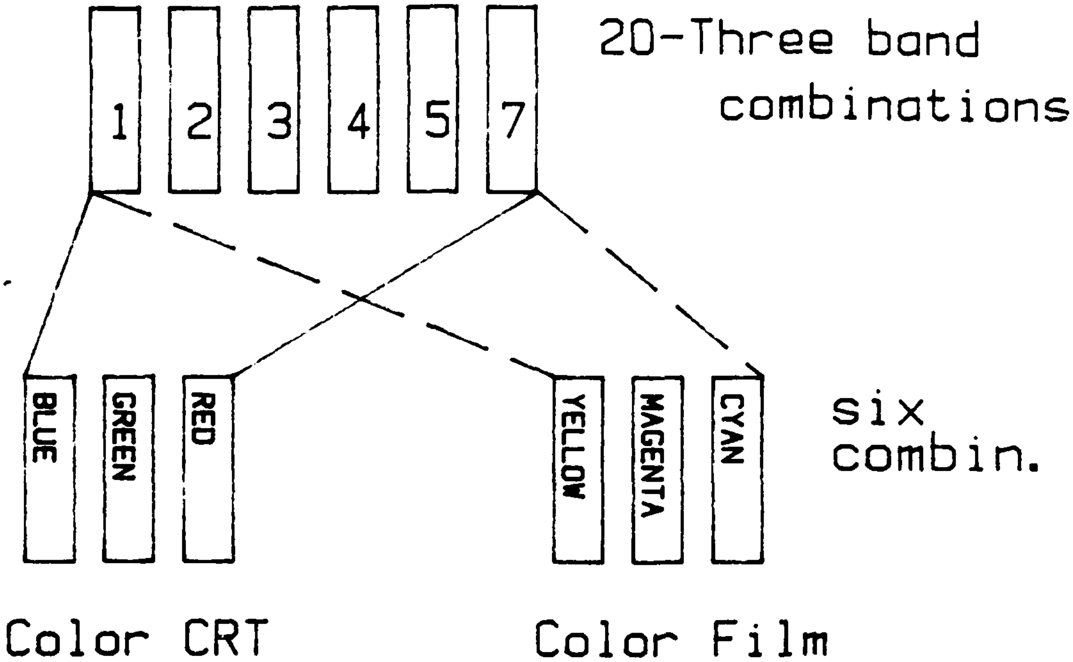


Figure 12. Brightness and Greenness Transformations of Spectra Mean Brightness Values in Landsat Thematic Mapper Bands 1-4 & 5.

LANDSAT Thematic Mapper Bands



120 Possible Combinations of
6 TM Bands Presented in Color

Figure 1: Illustration of the Number of TM Band - Color Medium Combinations

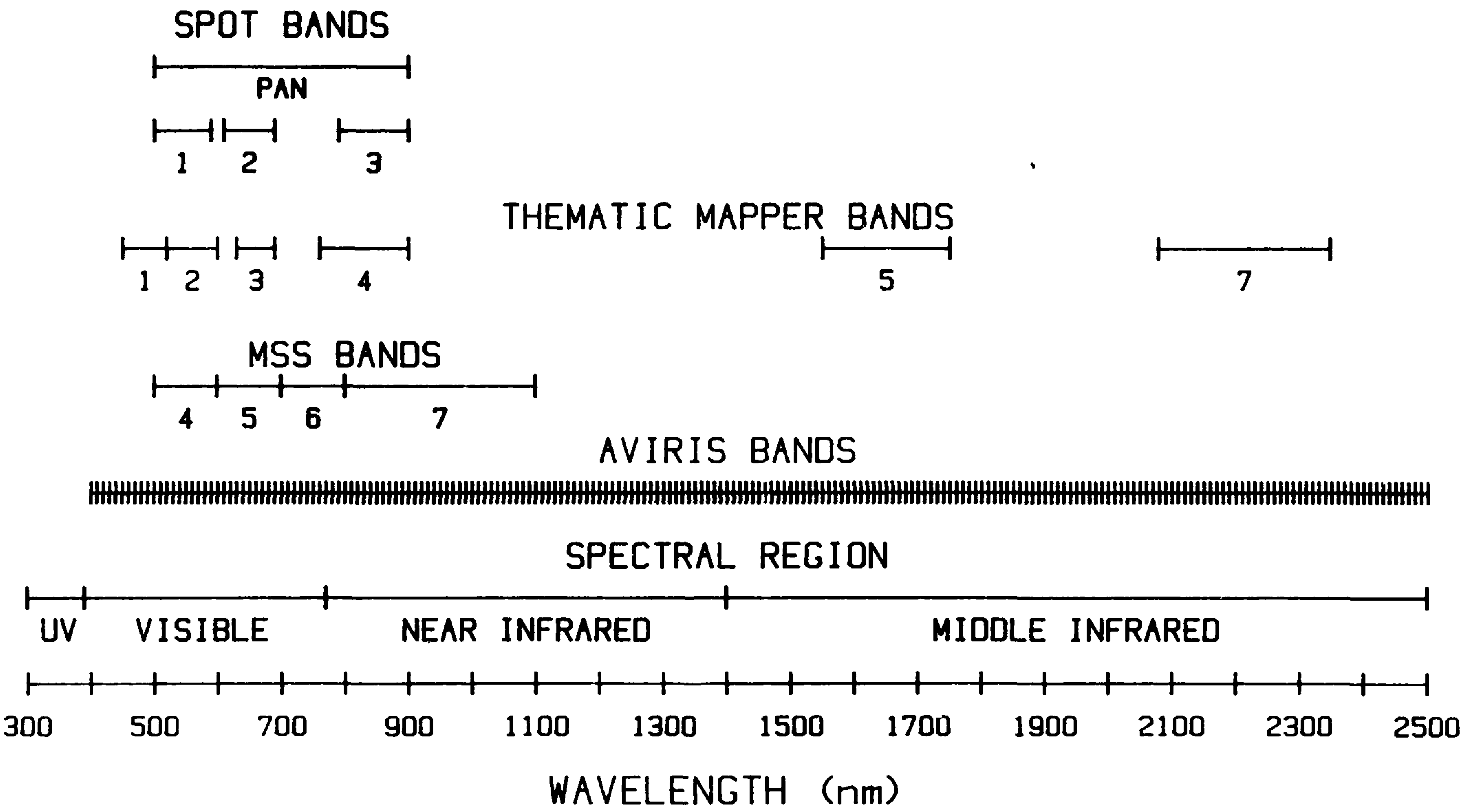


Figure 2. Spectral Bandpasses of Landsat MSS, Thematic Mapper, SPOT and AVIRIS

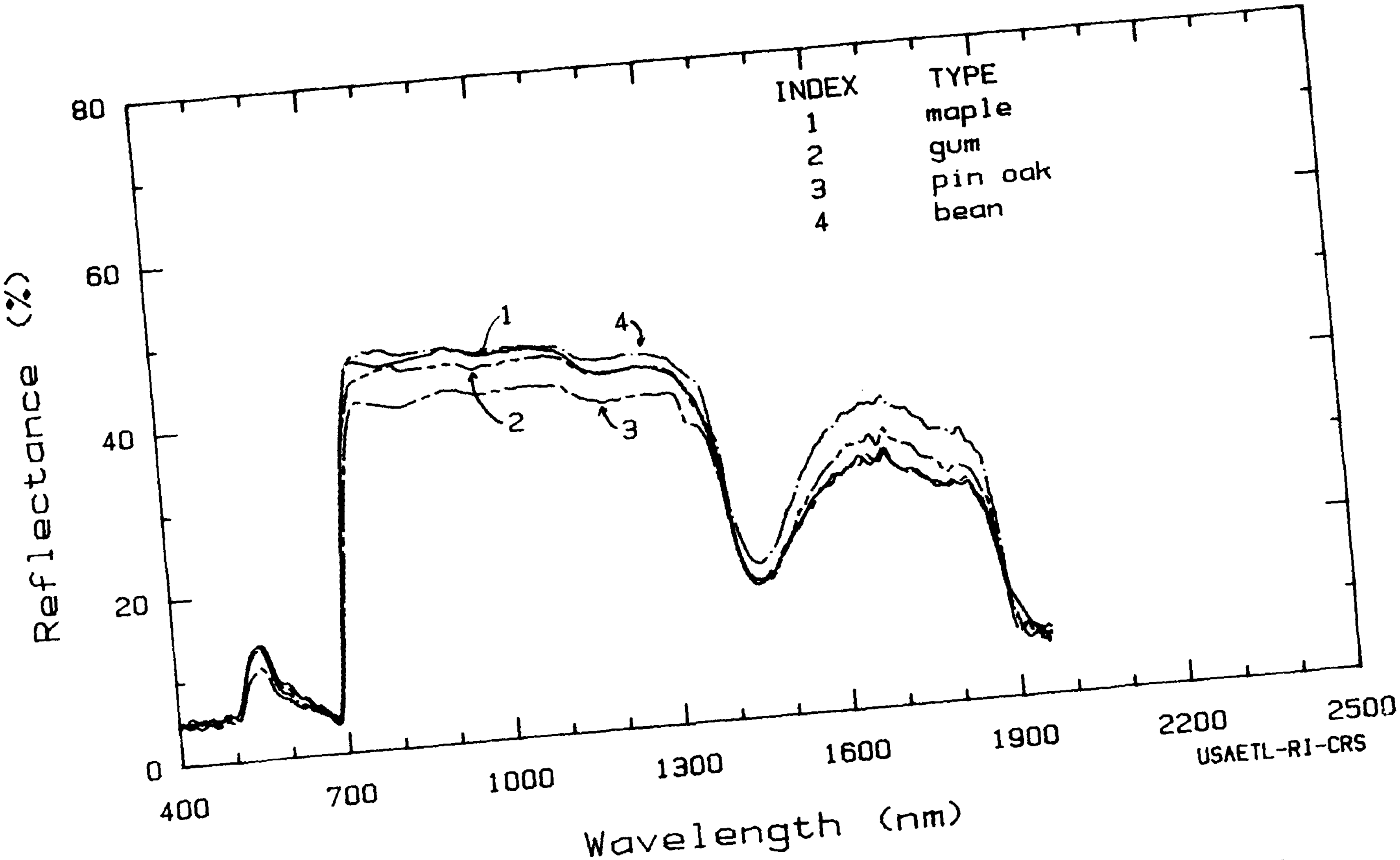


Figure 3. Reflectance Spectra of Green Plant Leaves. Ft. Belvoir, VA, October 1987.

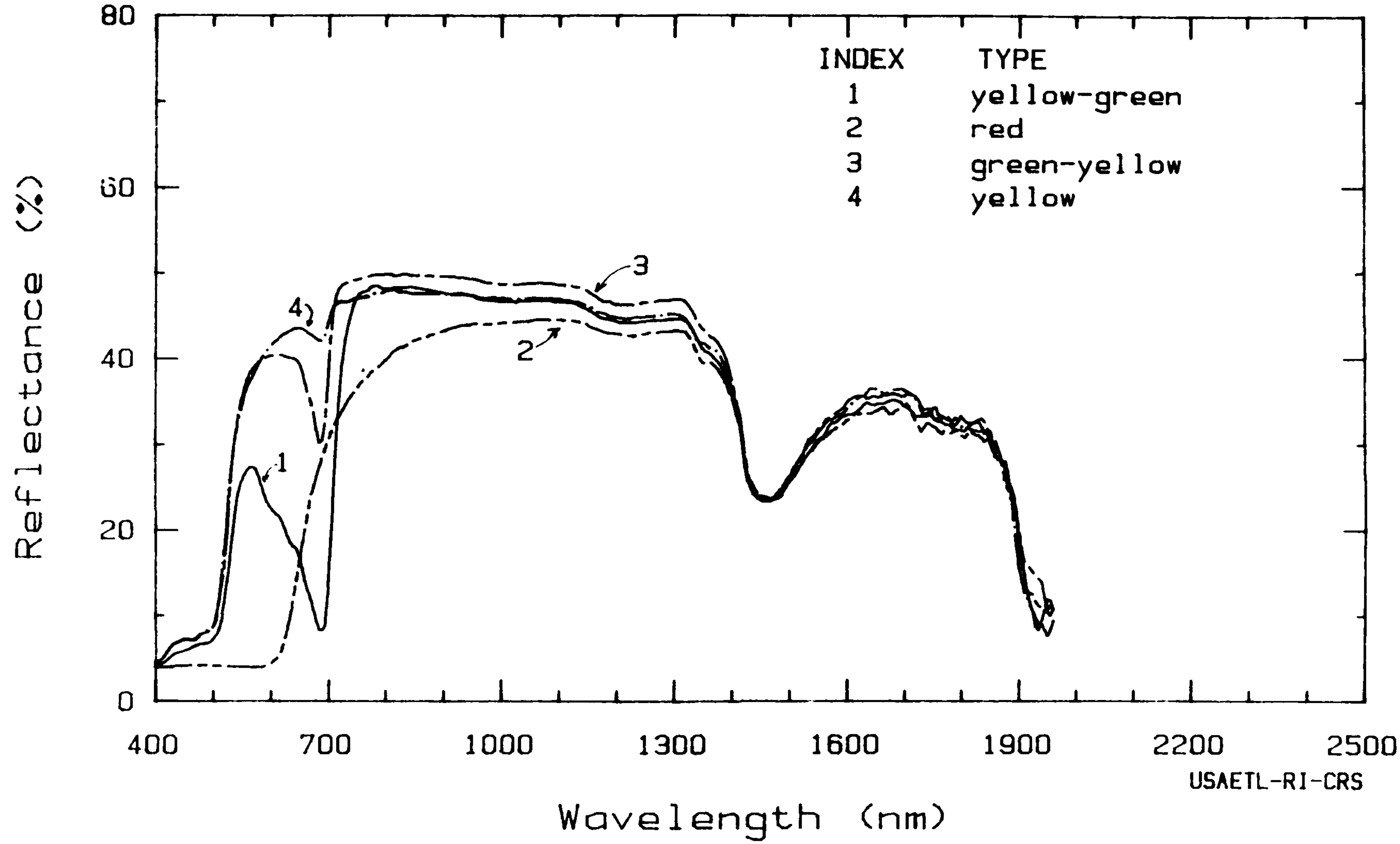


Figure 4. Reflectance Spectra Senescing Maple Leaves, Ft. Belvoir, VA, June 1987.

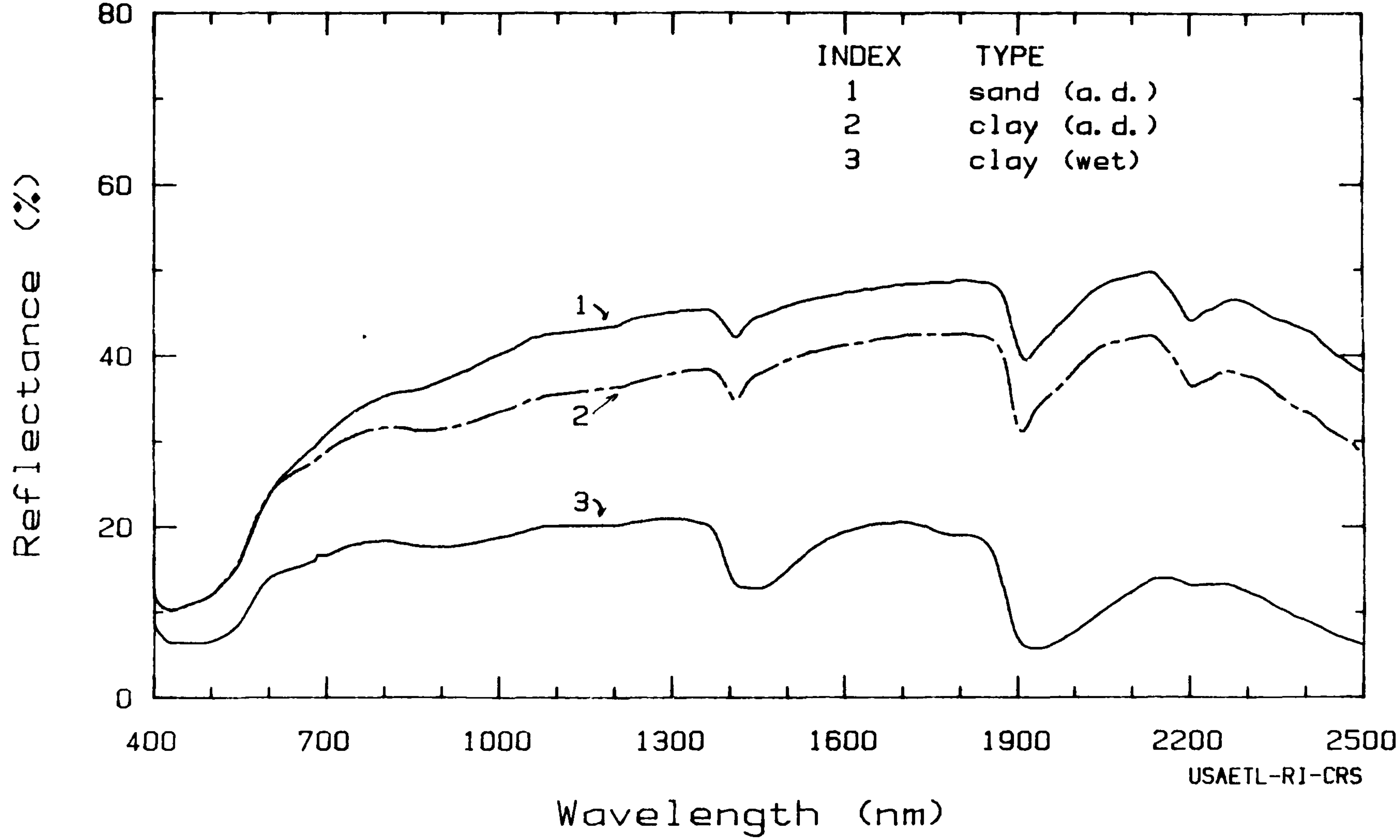


Figure 5a. Reflectance Spectra of Different Soils,
Ft. Belvoir, VA, June 1987.

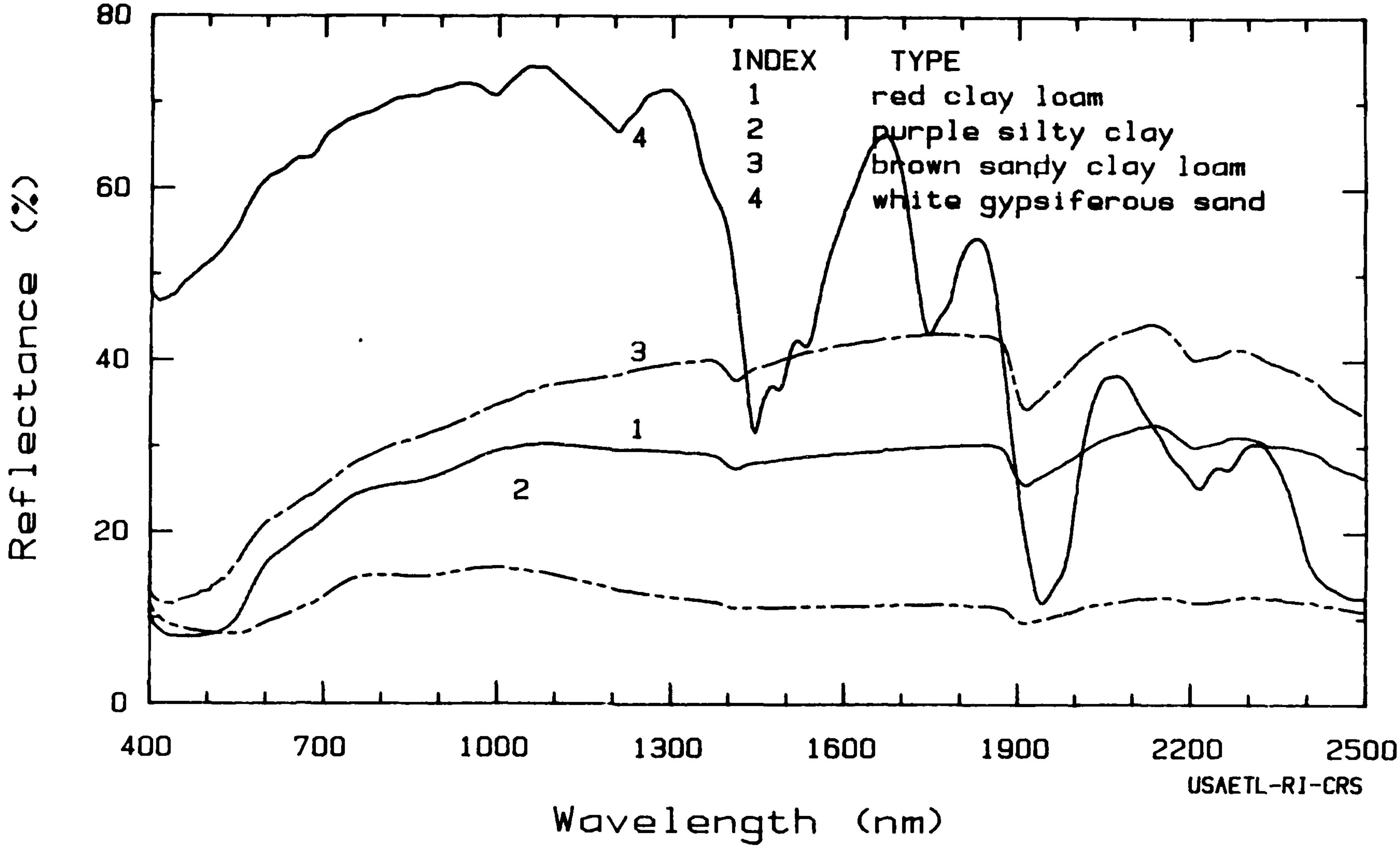


Figure 5b. Reflectance Spectra of Different Soils
Ft. Belvoir, VA, May 1988.

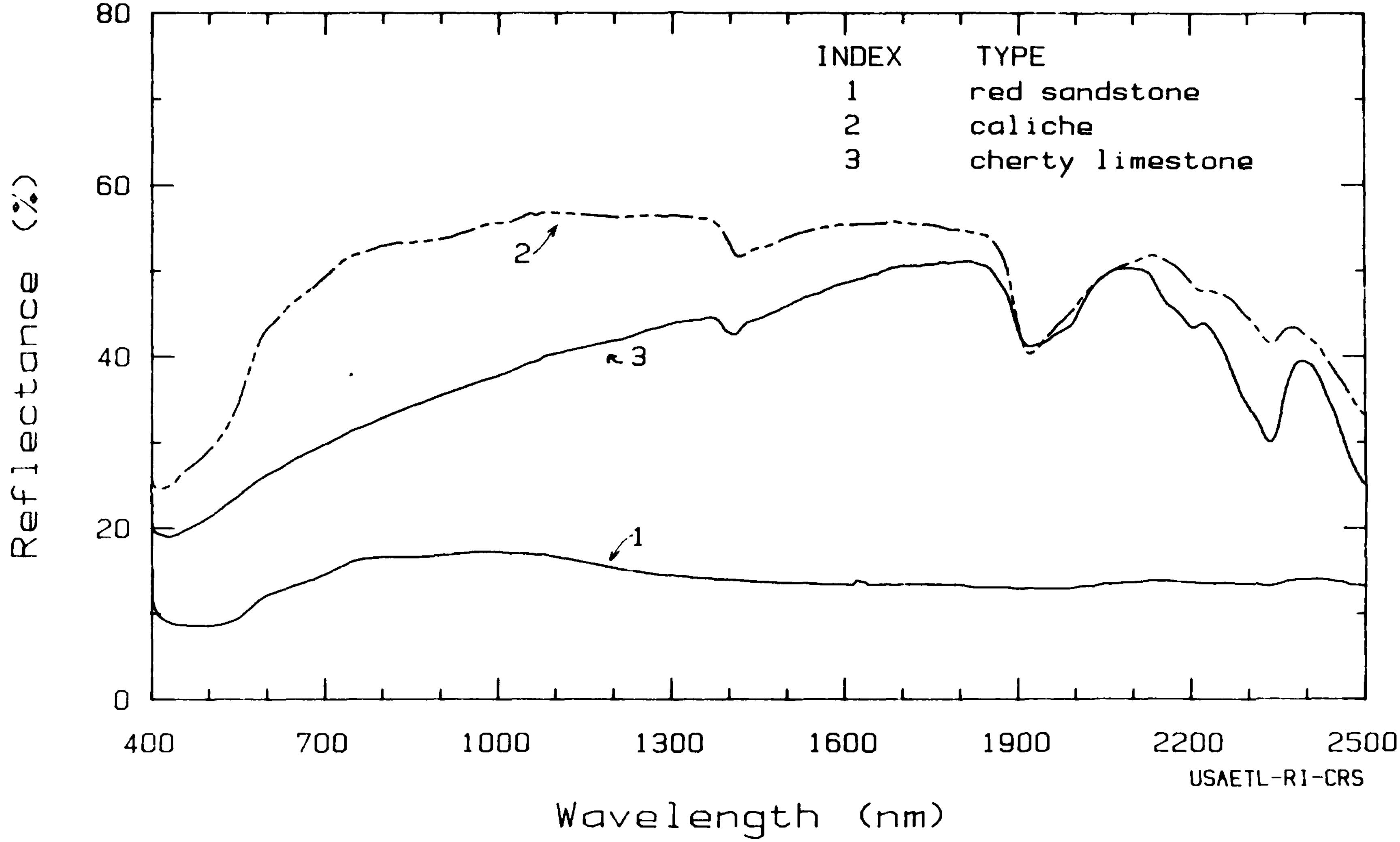


Figure 6a. Reflectance Spectra of Different Rocks, Ft. Belvoir, VA, May 1988.

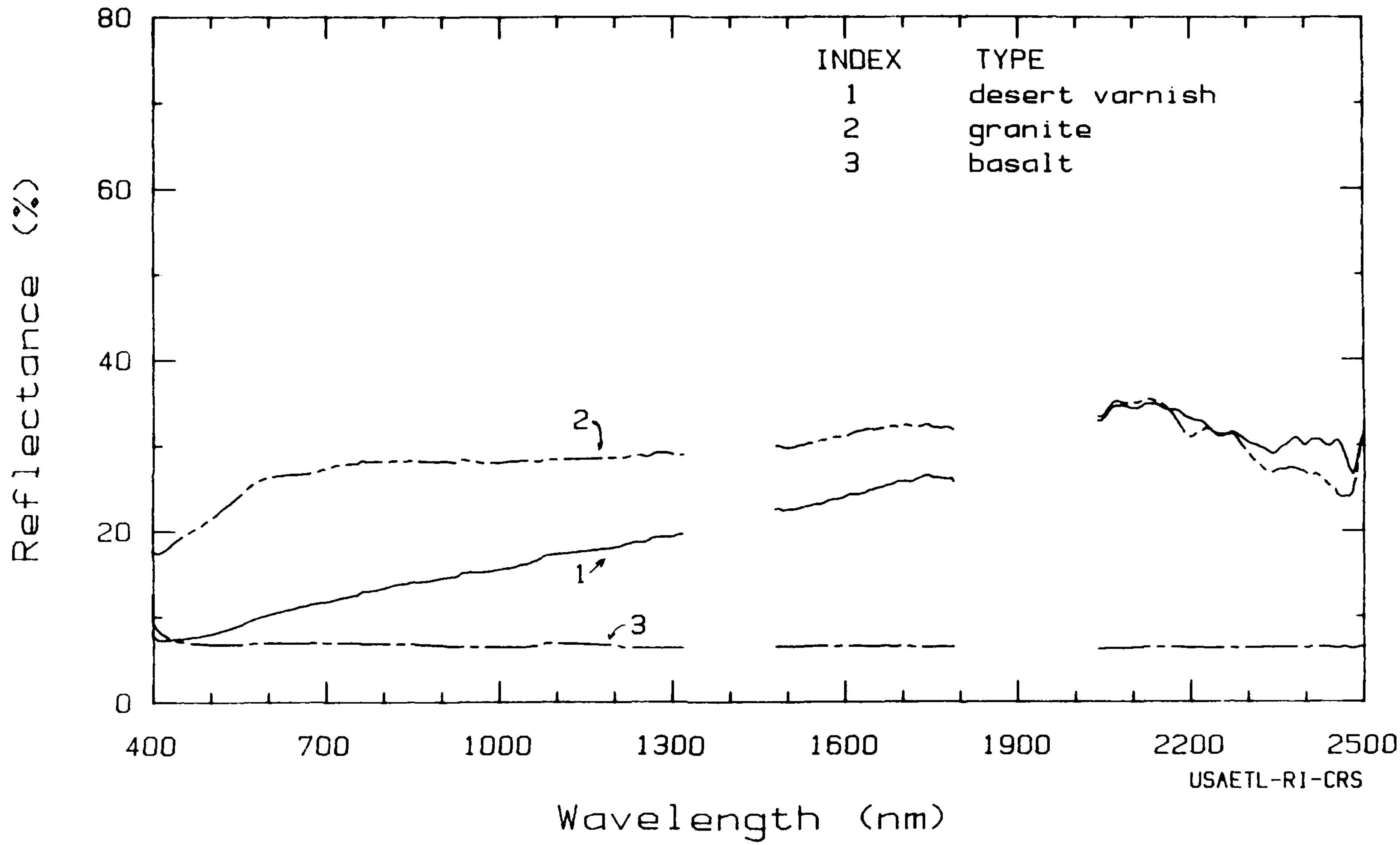


Figure 6b. Reflectance Spectra of Different Rocks, Ft. Belvoir, VA, May 1988.

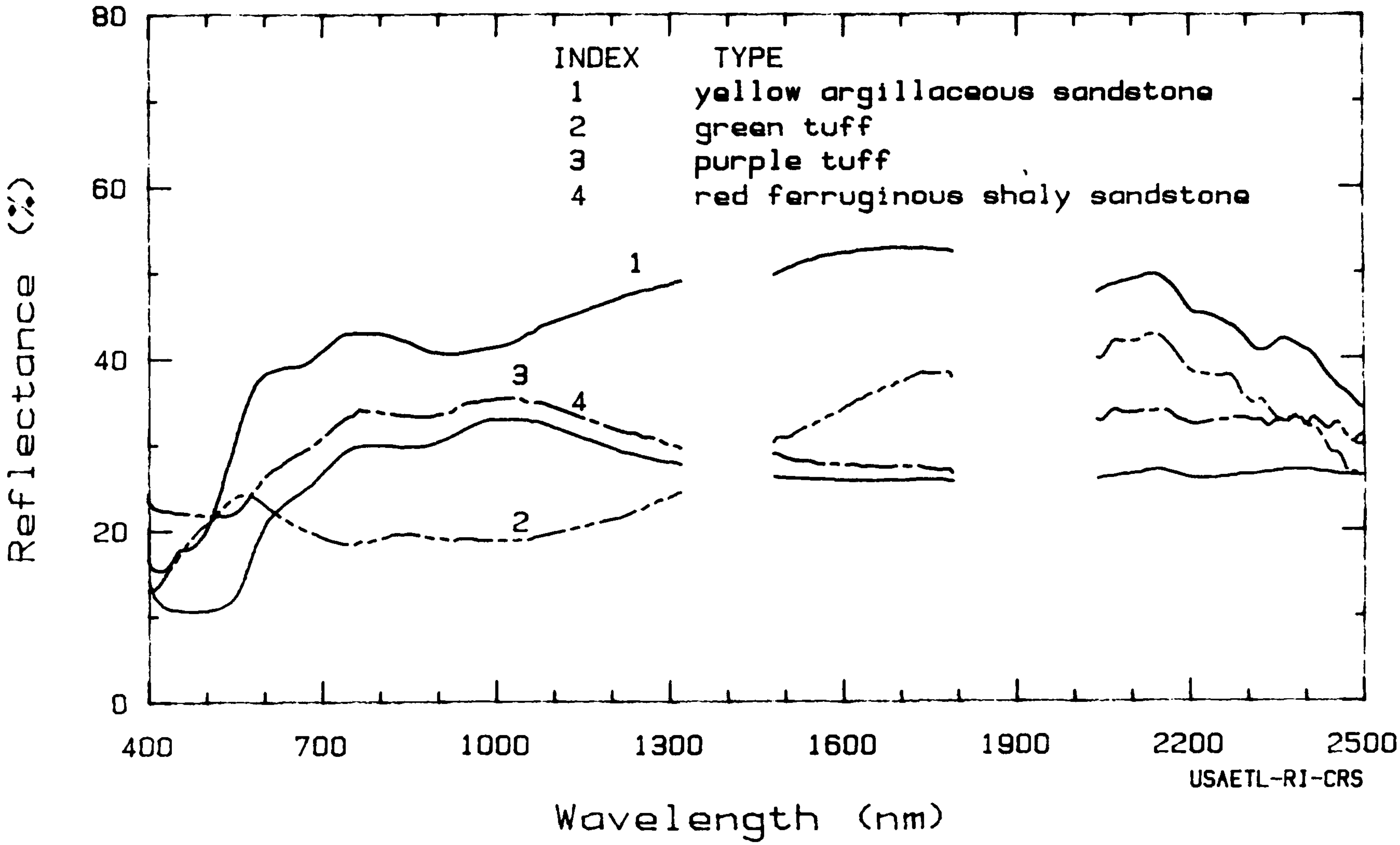


Figure 6c. Reflectance Spectra of Different Rock Surfaces, Ft. Belvoir, VA, May 1988.

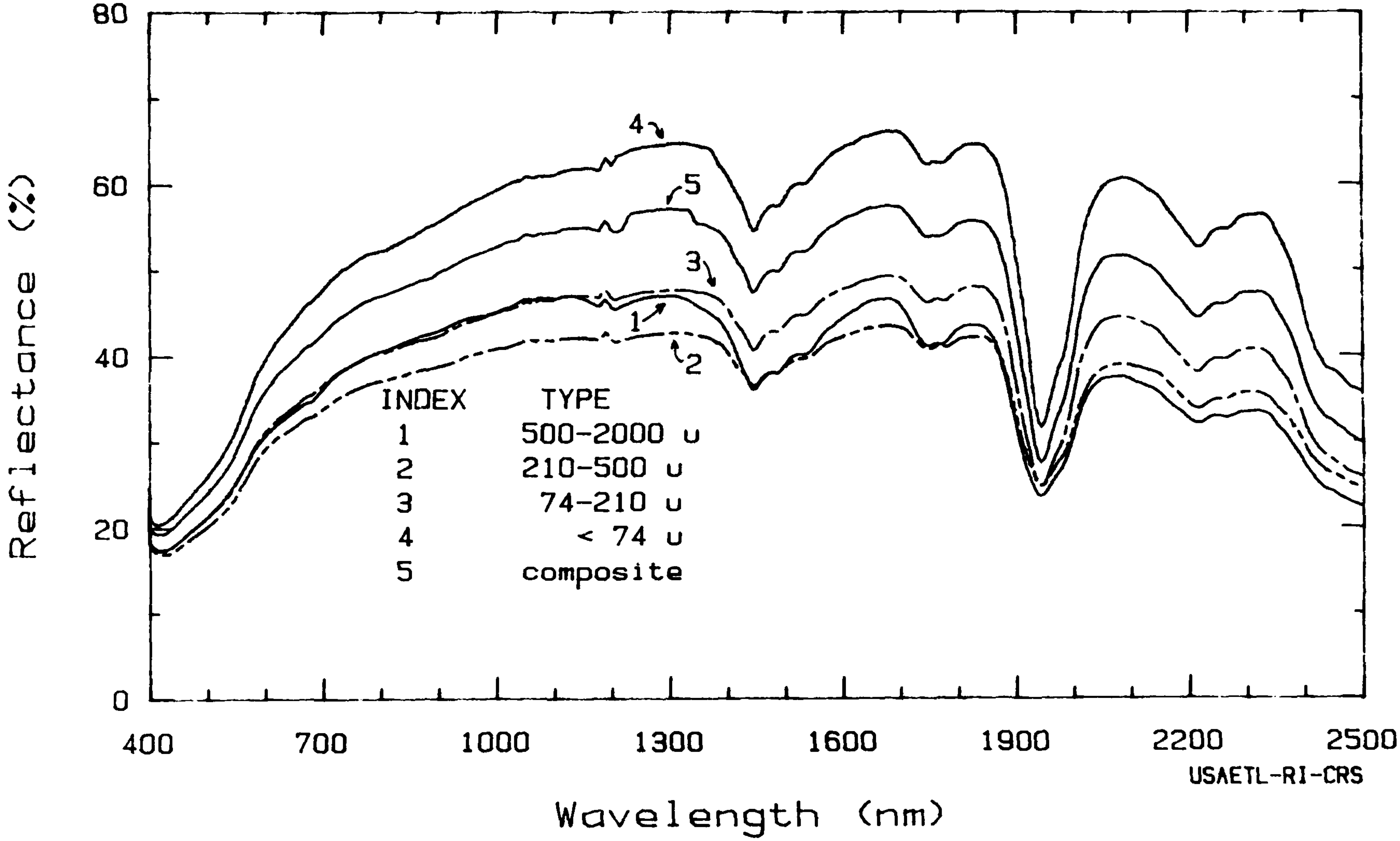


Figure 7. Reflectance Spectra Air Dry Silt Loam Sieve Separates. Ft. Belvoir VA. 2/87.

Laboratory Spectral Reflectance of Soil

Soil Texture: Silt Loam (air dry) Date Collected: 20 Feb 1986
Taxonomy: Aridisol Sample Number: AU-08
Mapping Unit: Dona Ana-Reagan Association 1/

Site Location: Dona Ana County, New Mexico, USA
32.7 deg. N. Latitude; 106.7 deg. W. Longitude

Procedures:

Spectroradiometric: Geophysical Environmental Research, Mark IV, spectroradiometer, SN:FBV-024; 4 degree field of view, spectral resolution 1.5 nm between 360 & 1300 nm, and 3.5 to 4.5 nm between 1300 & 2500 nm. Nadir viewing angle. Viewing height, 48.5 cm. Light source was a Lowel tota, 500 watt, Tungsten-Halogen lamp at a color temperature of 3200 degree K. Pressed Halon reference standard.

Sample: The air dried composite soil sample was passed through a soil sieve with openings of 2000 um and a subsample was taken (Index E). Remaining sample was passed through a nest of soil sieves with openings of 500 um, 210 um, 74 um, and pan. Each sieve separate was analyzed spectroradiometrically, (Indices A, B, C, and D, respectively). Moisture contents were determined gravimetrically at the time the spectra were taken.

Physical & Chemical Properties of Composite Sample: 2/

Composition: 40.0% Sand, 54.0% Silt, 6.1% Clay
Moisture Content: 4% to 11% (O.D. basis)

Mineralogy: Kaolinite, 7.9%; Fe-Oxyhy, 1.7%; Smectite, 7.7%; Mica, 11.4%; Calcite, 7.0%; Quartz, 32.3%; Gypsum, 29.5%

Ref: 1/ SCS-USDA, 1980, Soil Survey of Dona Ana Co., New Mexico.
2/ Ben Hajek, Unpublished soil data (sample AU8-E), Agron. Dept., Auburn Univ., AL.

Mean Reflectance(%) in Landsat 4 Thematic Mapper Bands.

Curve Index	Band 1	Band 2	Band 3	Band 4	Band 5	Band 7
	450-520 nm	520-600 nm	630-690 nm	760-900 nm	1550-1750 nm	2080-2350 nm
A	20.4	26.5	33.9	41.3	44.4	34.1
B	19.4	25.0	32.1	37.6	42.3	36.0
C	20.3	26.5	34.5	41.0	47.9	41.0
D	24.8	33.3	44.8	53.2	64.4	56.4
E	23.0	30.4	40.2	47.8	56.0	47.7

Compiled by: Melvin B. Satterwhite. Sheet No: 00008.
USAETL-RI-CRS.

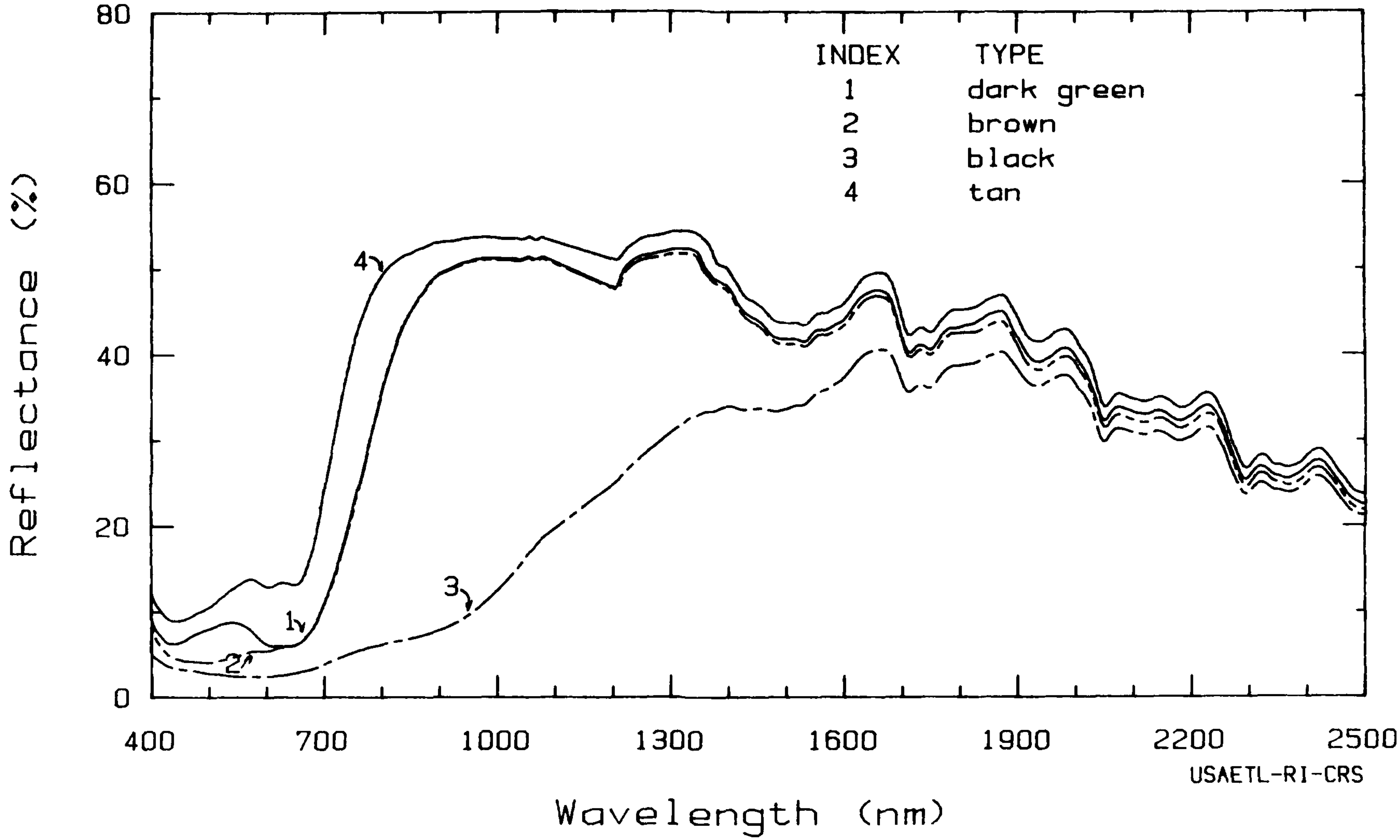


Figure 8. Reflectance Spectra of Woodland Fatigue Jacket, Ft. Belvoir, VA, October 1987.

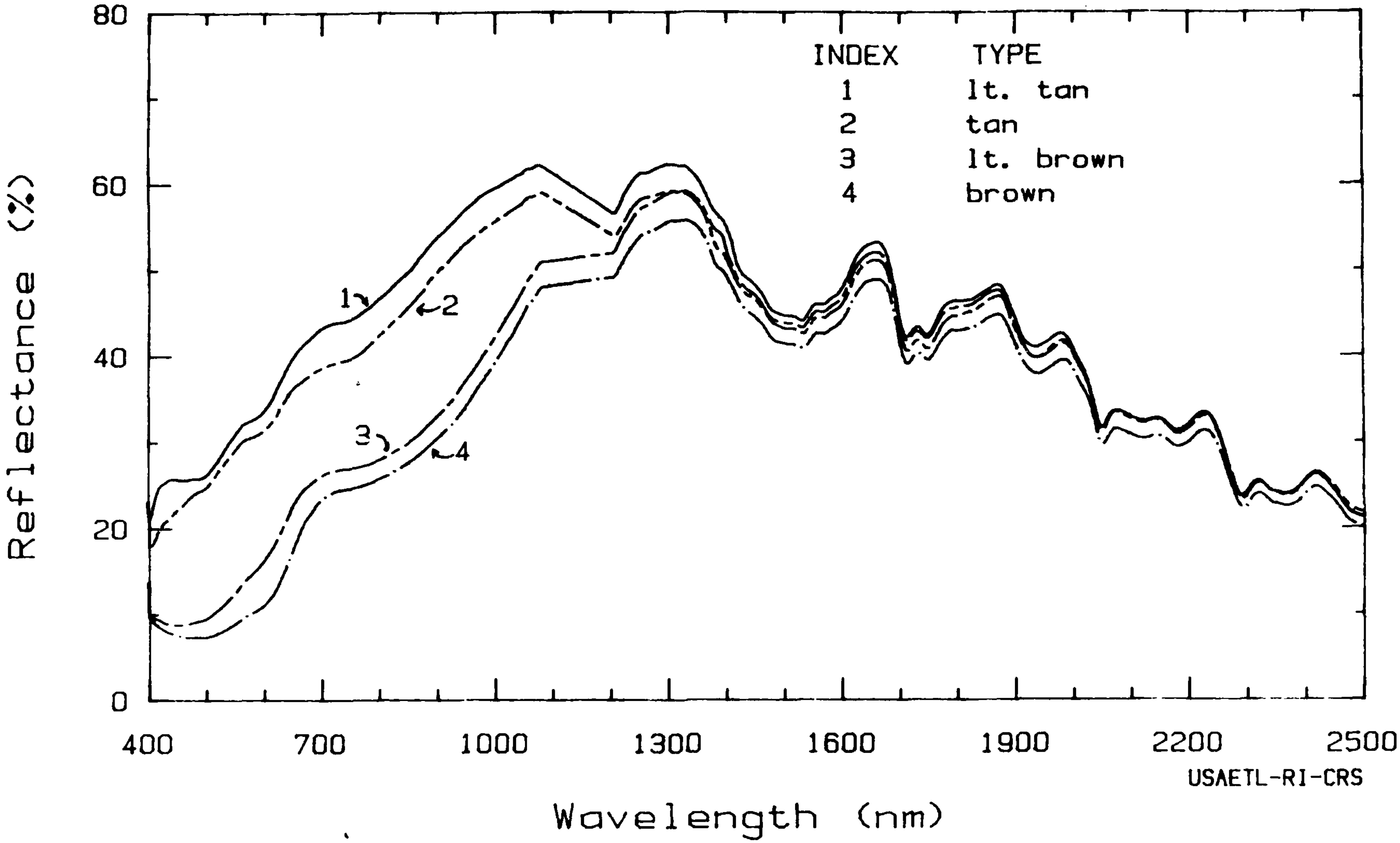
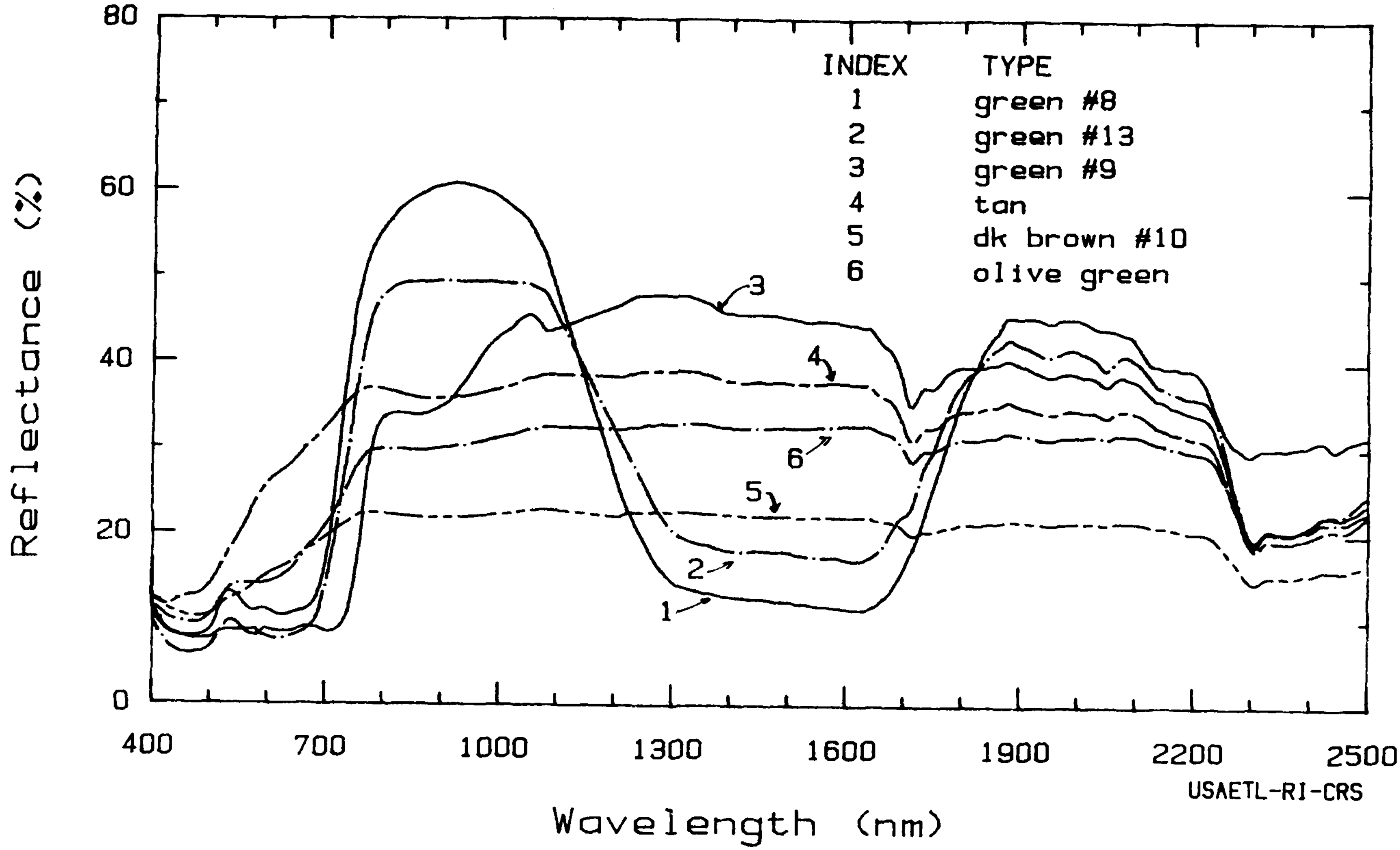


Figure 9. Reflectance Spectra of Desert Fatigue. Jacket, Ft. Belvoir, VA, September 1987.



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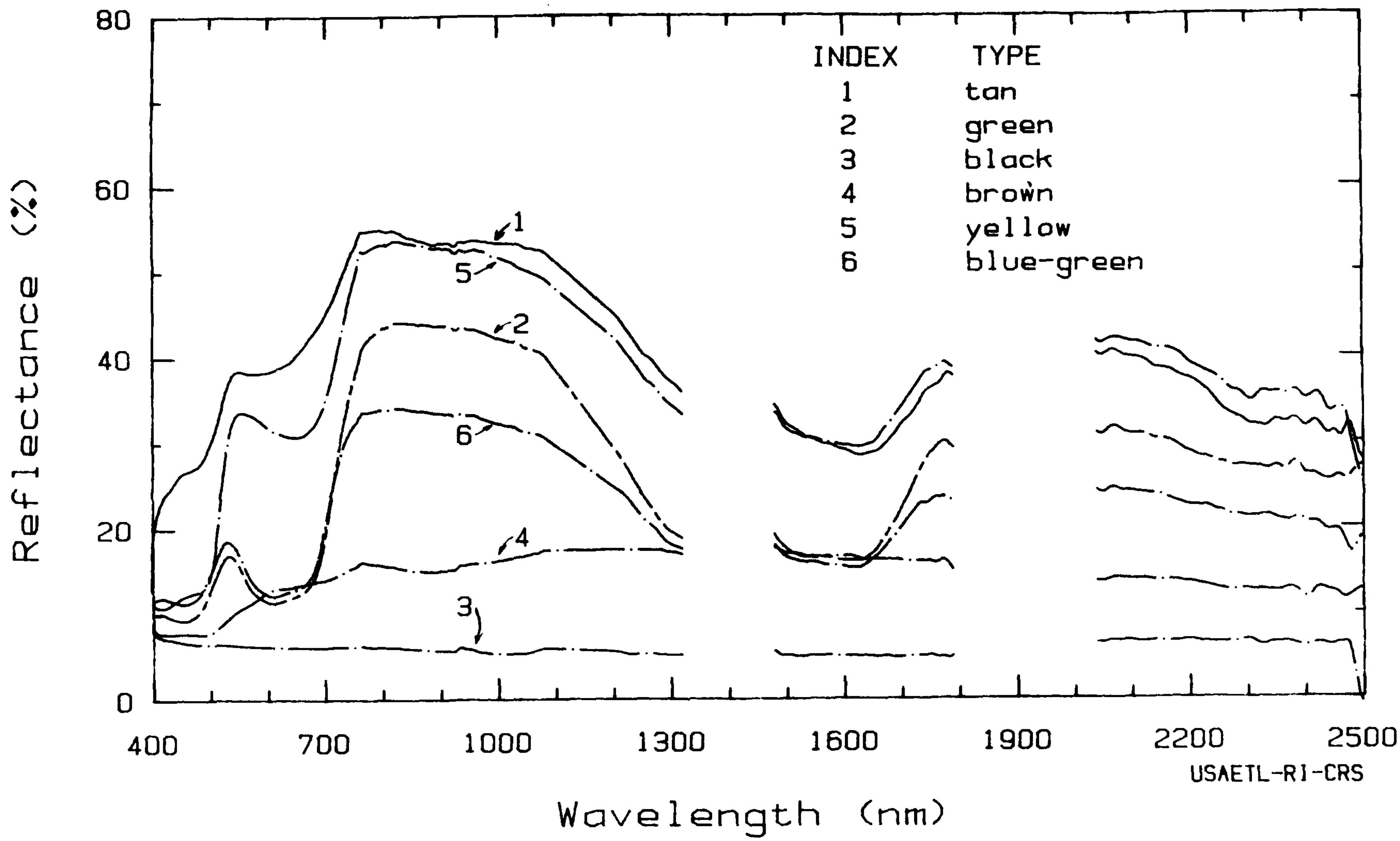

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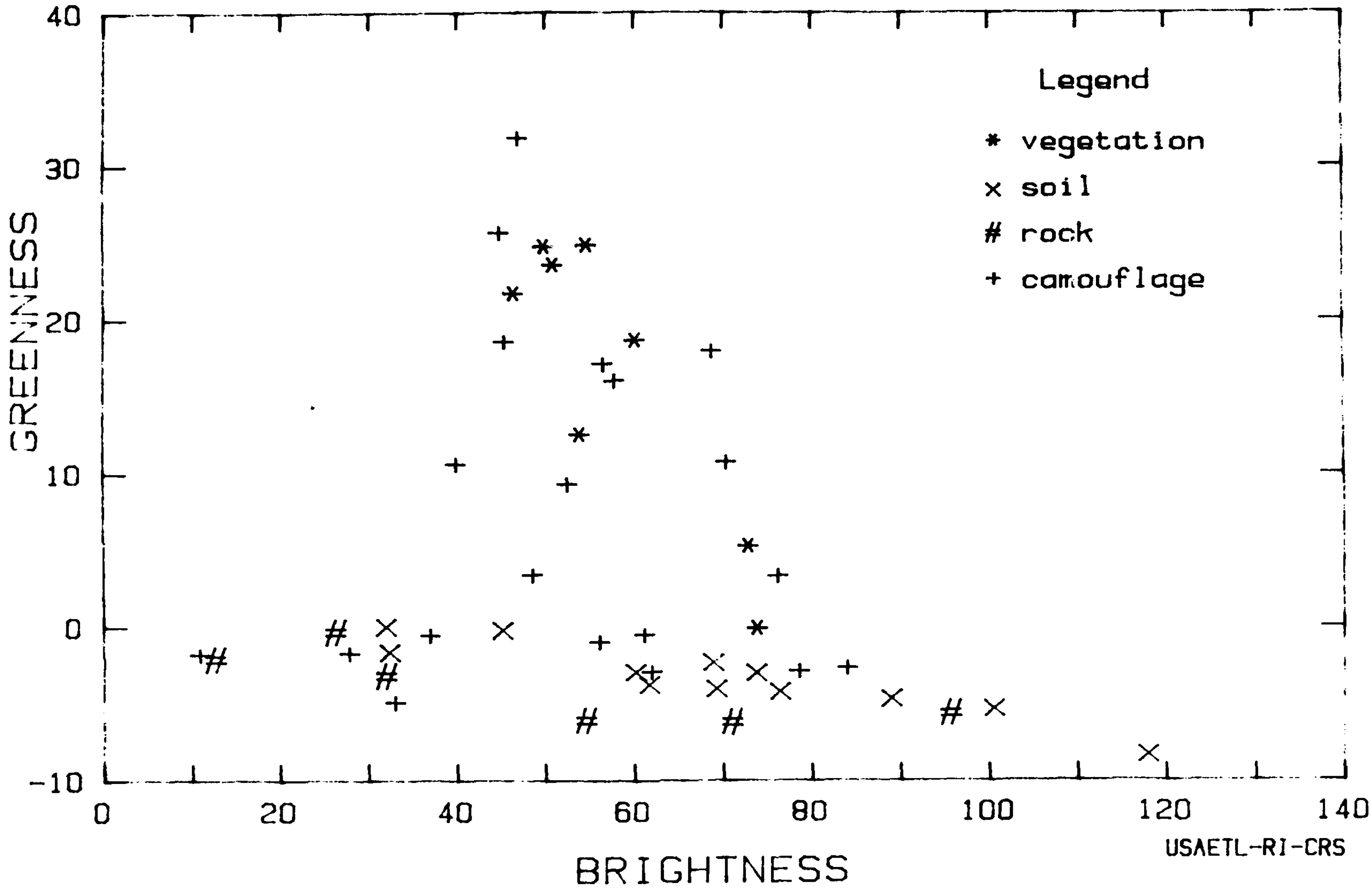

Figure 12. Brightness and Greenness Transformations of Spectra Mean Brightness Values in Landsat Thematic Mapper Bands 1-4 & 5.

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